TECHNOLOGY DEPT.

PUBLIC LIBRARY
MAR 10 1944

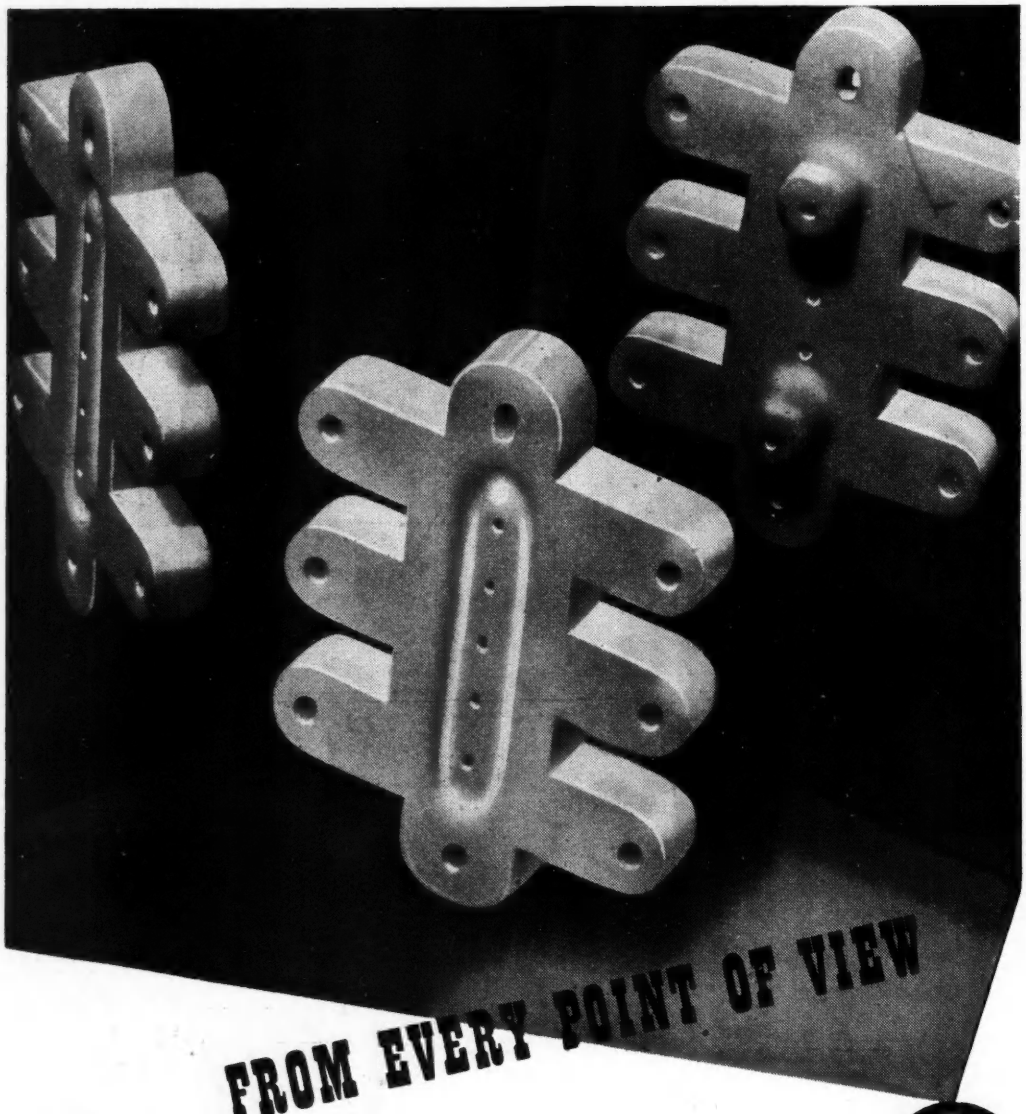
Electronic Engineering

INCORPORATING ELECTRONICS, TELEVISION AND SHORT WAVE WORLD

PRINCIPAL CONTENTS

Laminated Wood as an Insulator
Variable Frequency R.C. Oscillators—Part 2
The Recording of High Speed Transient Phenomena
Aerial Characteristics—Part 6 (Data Sheet)
Unusual Applications of the C.R.O.—Part 2

2/- FEB., 1944



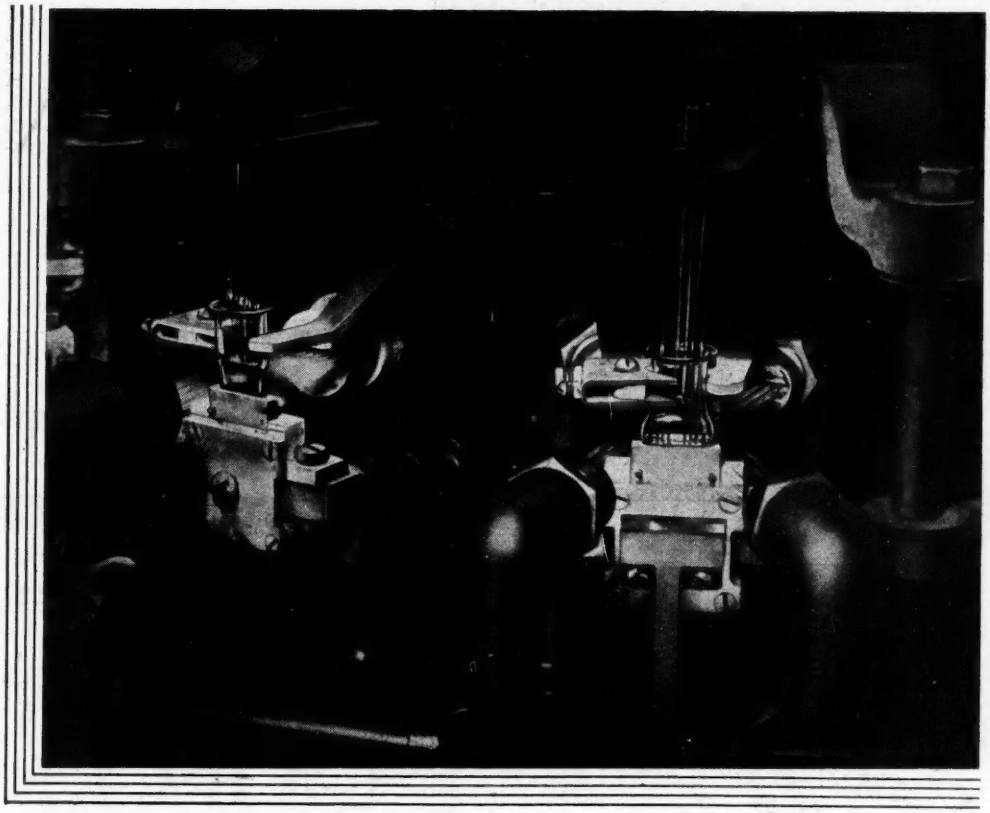
Frequentite is the most suitable insulating material for all high frequency applications. Ten years ago we introduced the first British-made low-loss ceramic, and consultation with us before finalising the design of new components is a wise precaution.

STEATITE & PORCELAIN PRODUCTS LTD.

Head Office: Stourport-on-Severn, Worcester. Telephone: Stourport 111. Telegrams: Steatain, Stourport.

The fact that goods made of raw materials in short supply owing to war conditions are advertised in this magazine should not be taken as an indication that they are necessarily available for export.

Stem Making



THE stem of a valve carries the lead wires which support the electrodes inside the bulb and also serve to carry the various currents.

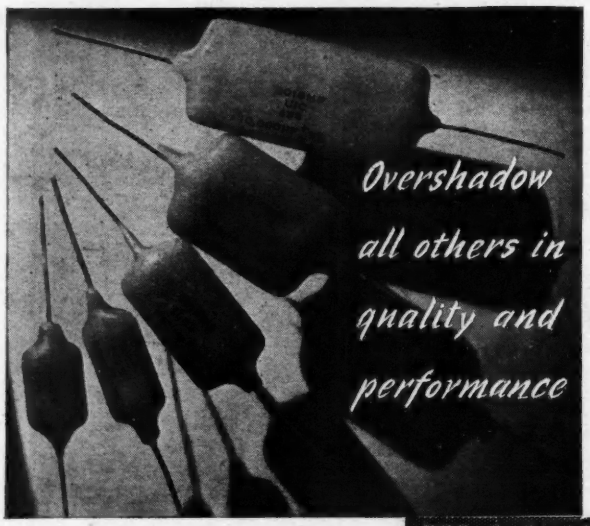
Our illustration shows these wires immediately after being fused into the stem to make the necessary vacuum tight joints.

BRIMAR
BVA
VALVES

STANDARD TELEPHONES AND CABLES LIMITED, FOOTSCRAY, SIDCUP.

U.I.C

SILVERED MICA CONDENSERS



Incessant progress in methods of manufacture and research linked with the most thorough mechanical and electrical inspection, are reasons for the outstanding superiority of U.I.C. Silvered Mica Condensers. Available in all standardized sizes. Suitable for tropical and arctic conditions. Type approved.

UNITED INSULATOR Co. LTD
12-22, LAYSTALL STREET, LONDON, E.C.1
Tel: TERminus 7383 (5 lines)
Grams: Calanel, Smith, London

THE PIONEERS OF LOW LOSS CERAMICS

It's hot—all the time! That's because the heating element is housed **inside the bit** in the Solon Electric Soldering Iron. Soldering is easier ; you get a neater, cleaner job in less time. All internal connections are housed at end of handle away from heat. A robust cord grip prevents sharp bending of the flexible lead. Complete with 6 ft. Henley 3-core flexible, Solon irons are made for the following standard voltages:— 100/110, 200/220, 230/250.

Supplies are of course, only available for essential war work. Early orders are advisable, as demands are heavy.

Made in England

Illustration shows a 125 watt standard model ; other types and sizes available.

SOLON Electric SOLDERING IRON

W. T. HENLEYS TELEGRAPH WORKS CO. LTD.
Eng. Dept., Milton Court, Westcott, Dorking, Surrey.

TELCON

TELCON CABLES

for

HIGH FREQUENCY TRANSMISSION and RECEPTION

Full particulars of all Telcon Products from :

THE TELEGRAPH CONSTRUCTION & MAINTENANCE CO. LTD.

Head Office : 22, Old Broad Street, London, E.C.2

Telephone : London Wall 3141

THERE IS NO SUBSTITUTE FOR ENGINEERING EXPERIENCE

*

And this is obviously a matter of extent, intensity and time.

Take Electrical condensers for instance—simple in conception maybe—but demanding infinite experience and skill, to satisfy the exacting operating conditions of modern requirements. The fulfilment of these has meant the whole time occupation of highly skilled specialists, working at high pressure, in this way to earn, along with their countrymen in other spheres, the right of survival.

What a wealth of experience and technical excellence will be available to all, when happier times arrive ; and nowhere more than in Dubilier Condensers.

DUBILIER
CONDENSER CO. (1925) LTD.

D.C.1

Value proved by long service

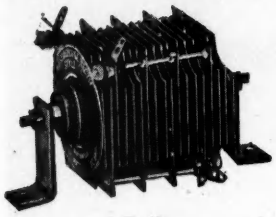
Osram Valves

MADE IN ENGLAND

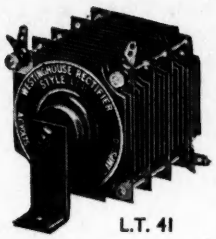
Ever since the advent of radio, Osram Valves have been closely connected with all the progressive stages of development in radio science. Intensive research still goes on, and improvements in design and technique to keep pace with the advancing times will ultimately be of benefit to all.

THE GENERAL ELECTRIC CO. LTD.
Magnet House, Kingsway - - London, W.C.1

L.T. UNITS in "WESTALITE"



L.T. 42



L.T. 41

TYPE	OUTPUT	
	VOLTS	AMPS
L.T. 41	12	1
L.T. 42	6	1
L.T. 44	12	2
L.T. 45	6	4

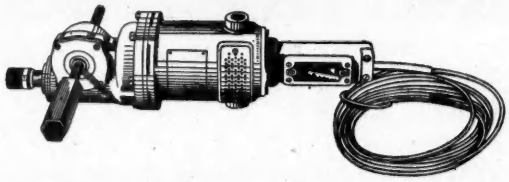
This range covers small rectifiers for charging batteries up to 6 lead acid cells, or supplying small resistance loads.

WESTINGHOUSE

METAL RECTIFIERS

WESTINGHOUSE BRAKE & SIGNAL CO., LTD.
Pew Hill House, Chippenham, Wilts.

We have over 25 years' experience



in designing and manufacturing a very varied range of Small Electric Motors, Alternators, Generators and Electro-Mechanical apparatus.

Our products are known throughout the world for reliability and stability under the most exacting conditions. In addition to producing special designs in quantity at competitive prices, we are interested in your experimental needs. As soon as they are released from the claims of war production our research and design laboratory together with our manufacturing resources will be at your disposal.

Write for particulars of any special type of apparatus that interests you: we will forward details and literature when available

SMALL ELECTRIC MOTORS LTD.

EST E S M 1914

BECKENHAM, KENT

A subsidiary of

BROADCAST RELAY SERVICE LIMITED

Electronic Engineering

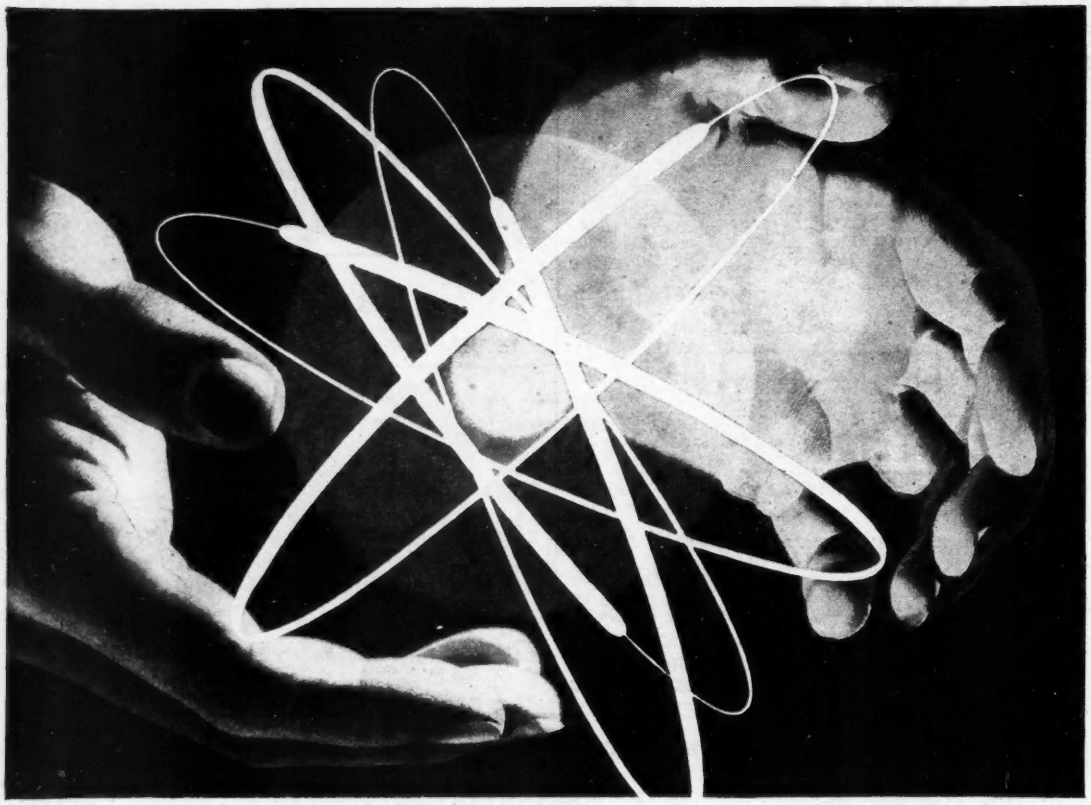
FEBRUARY, 1944

Volume XVI. No. 192.

CONTENTS

	PAGE
Editorial—Electronic Music	359
British Army Radio Link	360
Variable Frequency R-C Oscillators (concluded)	361
Laminated Wood as an Insulator	365
The Recording of High Speed Transient Phenomena	369
Grid Wires of High Strength and Conductivity	372
Data Sheets 59-62—Thin Cylindrical Aerials	373
Some Unusual Applications of the C.R. Tube	378
H.F. Oscillations from Thyratrons ...	380
High Frequency Therapy—Part VI	382
February Meetings	386
Dust Cores—Correspondence	388
Notes from the Industry	391
Abstracts	392
Book Reviews	394

CONDITIONS OF SALE—This periodical is sold subject to the following conditions, namely, that it shall not without the written consent of the publishers first given, be lent, re-sold, hired out or otherwise disposed of by way of Trade except at the full retail price of 2/- and that it shall not be lent, re-sold, hired out or otherwise disposed of in a mutilated condition or in any unauthorised cover by way of Trade, or affixed to or as part of any publication or advertising, literary or pictorial matter whatsoever.



THIS IS MAGIC 1944

Through thick fog a 'plane flies safely to its base; makes a perfect landing. In a factory a wisp of smoke appears and an automatic-warning sounds the fire-alarm almost before the fire is started. A new machine records the thought-impulses of the brain. X-rays reveal the ills of human tissues, the flaws of massive metal castings—All this is the magic of electronics—the science of the electron.

Born only at the beginning of the century, this wonder-science now speeds our industry, contributes to our safety, combats disease, probes the mysteries of the universe—And, already established as a landmark in the short history of electronics, Mazda Valves and the organisation behind them journey on towards an era of new and dazzling progress—The Electronic Era.

MAZDA valves

FOR INDUSTRIAL, MEDICAL, SCIENTIFIC AND DOMESTIC APPLICATIONS

THE EDISON SWAN ELECTRIC CO. LTD. 155 CHARING CROSS RD., LONDON, W.C.2
(R.M.14)

PROPRIETORS
HULTON PRESS LTD.

Electronic Engineering

EDITOR
G. PARR.

EDITORIAL, ADVERTISING AND PUBLISHING OFFICES, 43-44, SHOE LANE, LONDON, E.C.4

TELEPHONE:
CENTRAL 7400

Monthly (published last day of preceding month) 2/- net. Subscription Rates: Post Paid to any part of the World—3 months, 6/6; 6 months, 13/-; 12 months, 26/-. Registered for Transmission by Canadian Magazine Post.

TELEGRAMS:
HULTONPRES LUD
LONDON.

Electronic Music

THE replies to the recent suggestion to form a Discussion Group on Electronic Musical Instruments have shown that a considerable number of readers of this journal are interested in this unique application of electronics.

Although the subject has been studied for many years there is little published literature on it in English, and in this country the only recent survey was that given in the paper by J. T. Winch and A. M. Midgley in the *Journal of the Institution of Electrical Engineers**.

Those readers who were able to attend the meeting on January 8th (announced in last month's issue) agreed that the formation of a discussion group would serve a very useful purpose in increasing the knowledge of the subject and exploring its possibilities as a post-war development of importance in the electronic field.

A wide range of interests was represented, from the professional to the beginner, and one of the tasks of the small committee that has been elected is to reconcile all interests with the future programme that is being planned.

The advisability of forming yet another specialist society is a question which will also receive careful consideration. So far the non-committal word "group" has been used to refer to the meeting until a definite policy justifies a change in title. As implied in a recent editorial note in this journal, the *raison d'etre* of a scientific society is decided by its members, but in the case of a small body of enthusiasts the decision to stand on their own feet is governed by the difficulties of organization and finance.

There already exists an Institute of Musical Instrument Technology, whose members are drawn from the musical instrument trades, and it seems reasonable that electronic musical instrument designers should have a liaison with such a body. The Institute, whose headquarters are at the Northern Polytechnic, Holloway, has already offered its hospitality to the group for their preliminary discussion and this encouragement is gratefully acknowledged.

In the meantime it has been decided to circulate a questionnaire to those who have registered their names with this journal to find out their particular wishes and interests. On the information supplied, the committee will be able to draw up a programme of lectures and demonstrations for the forthcoming months which shall have the widest possible appeal. Readers who have not yet supplied their names are invited to apply for a copy of the questionnaire, replies to which should be returned before February 15th.

The next meeting of the Group will be held at the Northern Polytechnic on Saturday, March 4th, at 2.30 p.m.

The subject of the meeting will be announced in next month's issue.

* Vol. 86, p. 517, 1940.

ELECTRONIC ENGINEERING MONOGRAPHS

The second booklet in the series of Electronic Engineering Monographs is now at press and will be ready at the end of January. The title is:

PLASTICS IN THE RADIO INDUSTRY

by E. G. Couzens, B.Sc., A.R.C.S. and W. G. Wearmouth, Ph.D., F.Inst.P.

and the subject matter is based on a series of articles which have appeared in this journal, completely revised and expanded to include information on the manipulation of Plastic Materials

The Monographs are obtainable through technical booksellers or direct from the Publishers at 43 Shoe Lane, E.C.4, price 2/6 or 2/8 post free.

Copies of the Monograph on

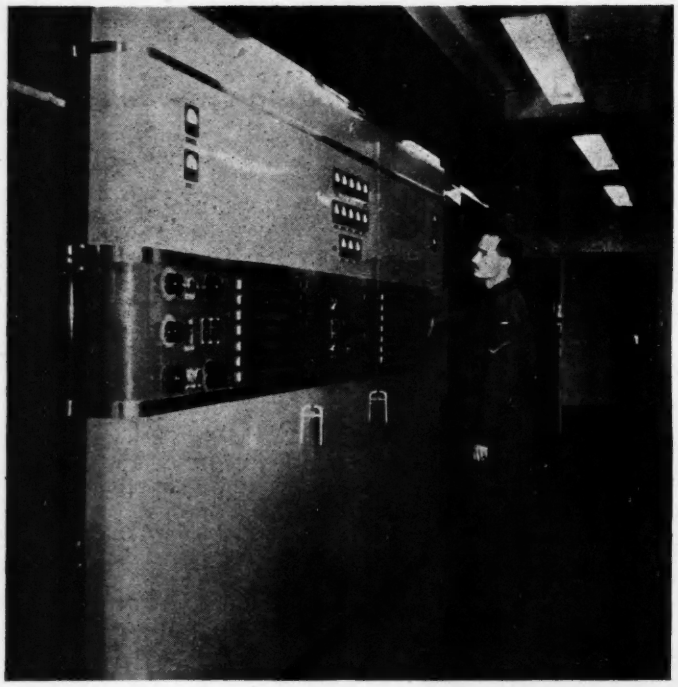
FREQUENCY MODULATION

by K. R. Sturley, Ph.D.

are still available, price 2/8, post free.

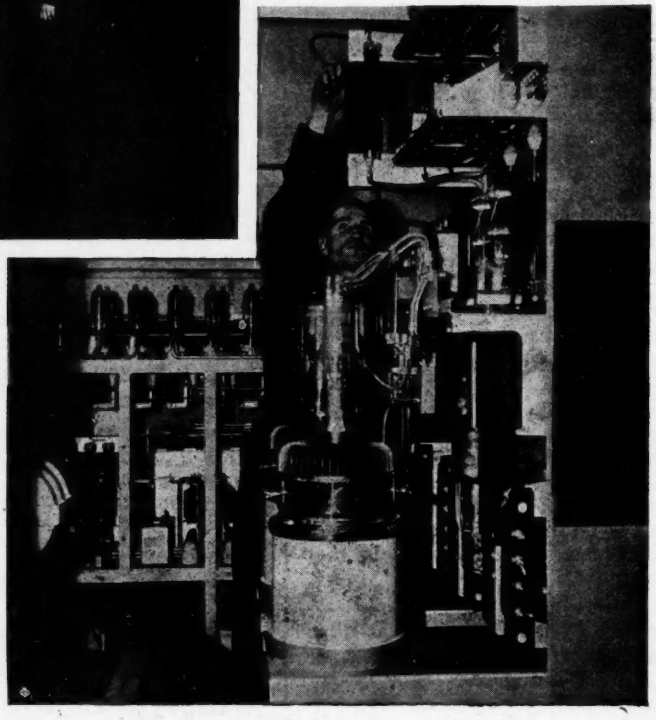
Early application for both monographs is recommended as the number of copies is limited under the present paper restrictions.

British Army Radio Link



THE pictures show a new War Office transmitting station " Somewhere in England " operating a high-speed wireless telegraph service to distant theatres of war and handling vast quantities of traffic. The operating staff are located in London and the transmitters are keyed by means of voice-frequency tone signals passed over land lines to the station.

British official photograph (War Office) Crown copyright reserved.



THE Royal Signals provide direct radio communication from the War Office to all theatres of war and many other places besides.

The radio transmitting and receiving stations forming the home terminals of the Army Wireless Chain have been built since the war began at secret locations in the country and are manned by men of the Royal Signals, most of whom had no civilian experience of high-power, high-speed radio communication.

F

T
o
R
the fre
mately
all th
to R
The si
freque
air con
to give
to var
that a
each
maxim
metho
mercia
variab
ranges
Using
resisto
accoun
For ex
tor wi
mum i
8 meg

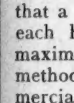


Fig. 9.

Owing
of suc
stabilit
better
fixed c
range,
of low
These
subject
use an
continu
does a

In or
Wigan
method
of R.C
has be
recent
the fre
it can
decade
accordi
case o
would
decade
gang d
being t

* Messrs

Variable Frequency Resistance Capacity Oscillators

By J. A. B. DAVIDSON, B.A.*

(Continued from page 319 of the January issue)

THERE are a number of methods of varying the frequency of R—C oscillators. In all types the frequency is found to be approximately proportional to $1/RC$ when all the tuning resistances are equal to R and the capacities equal to C. The simplest method of varying the frequency is to use ganged variable air condensers, which can be arranged to give a sweep of at least 10: 1, and to vary the resistances in steps so that a number of ranges are obtained, each having the same minimum to maximum frequency ratio. Another method which has been found commercially practicable is to use ganged variable resistors and to change the ranges by means of fixed condensers. Using the first method composition resistors are normally employed on account of the high values required. For example, in the Willans oscillator with condensers of .001μF maximum it is necessary to use resistors of 8 megohms to get down to 20 c/s.

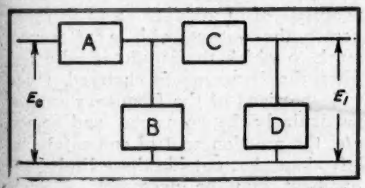


Fig. 9. General 2-stage network suitable for Willans oscillator.

Owing to the temperature coefficients of such resistors the long period stability of the oscillator cannot be better than about 3 or 4%. When fixed condensers are used to change range, wire-wound variable resistors of lower values can be employed. These are reasonably stable, but are subject to rapid wear in continuous use and do not produce a smooth continuous variation of frequency as does a variable air condenser.

In order to escape these limitations, Wigan[14] has proposed a decade method of controlling the frequency of R.C. oscillators, and advantage has been taken of this principle in recent design. It will be clear that if the frequency is proportional to $1/RC$ it can be made direct reading in decade dials, if $1/R$ or $1/C$ is varied according to a decade law. In the case of the Willans oscillator this would require either a two gang decade conductance box or a two gang decade elastance box, elastance being the reciprocal of capacity.

* Messrs. Muirhead & Co., Ltd.

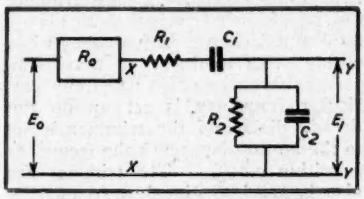


Fig. 10. Willans oscillator network.

Such a tuning system using four dials can be arranged to vary the frequency over a range of 10,000 to 1, while the decade facility allows the frequency to be set with extreme precision. If a decade elastance box is used the decade principle can be applied with ease to almost any R—C oscillator and the accuracy of the generated frequency will be that of the elastance box itself provided that over the entire range of frequencies the unwanted phase shift in the amplifying section is negligible. Owing, however, to the finite output impedance of the amplifying section, this does not apply in the case of resistance tuning.

Consider the network of Fig. 9 wherein A, B, C and D represent impedances:

This is the general 2-stage network suitable for use with the Willans oscillator.

The expression connecting the input voltage E_0 and the output voltage E_1 is

$$\frac{E_0}{E_1} = 1 + \frac{A}{D} + \frac{A}{B} + \frac{C}{D} + \frac{AC}{BD} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The particular form of network most suitable for the Willans oscillator is shown in Fig. 10, where R_0 denotes the amplifier output impedance which must be considered in series with R_1.

It can easily be shown from (1) that

$$\frac{E_0}{E_1} = 1 + \frac{R_0 + R_1}{R_2} + \frac{C_2}{C_1} + j\left\{\omega C_2 (R_0 + R_1) - \frac{1}{\omega C_1 R_2}\right\} \quad (2)$$

The voltages E_0 and E_1 will be in phase with each other if

$$\omega^2 = \frac{1}{C_1 C_2 R_2 (R_1 + R_0)}$$

and this formula will give the frequency generated by connecting between the points XX and YY an amplifier having output impedance equal to R_0, zero phase shift and gain equal to $1 + \frac{R_1 + R_0}{R_2} + \frac{C_2}{C_1}$.

If $R_1 = R_2 = R$ and $C_1 = C_2 = C$, ω becomes equal to $\frac{1}{RC\sqrt{1 + R_0/R}}$ and the gain becomes equal to $3 + \frac{R_0}{R}$.

It is thus seen that if R is kept fixed and R_0 does not vary, the frequency will be truly proportional to $1/C$ and the maintenance condition will be constant.

If, on the other hand, C is kept fixed and R varied the frequency will not be proportional to $1/R$ unless R_0/R is constant, a condition which is awkward to achieve in practice. Wigan[14] has found, however, that by adding an extra fixed resistance to the network, the effect of R_0 can be eliminated and the frequency made truly proportional to $1/R$. In practice, of course, the advantage of resistance tuning over condenser tuning is very marked on the score of cheapness, compactness and ease of adjustment of values.

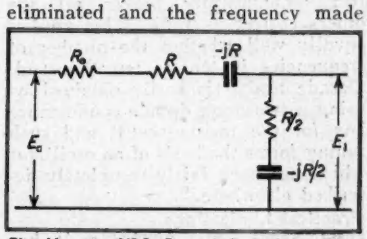


Fig. 11. $\omega_0 = 1/RC$. E_0 and E_1 not in phase.

Consider again the network of Fig. 10. If the C's and R's are equal, at a frequency $\omega_0 = 1/RC$ this reduces to that shown in Fig. 11, and it is obvious that at this frequency the two voltages E_0 and E_1 will not be in phase with each other. If, however, we add a resistance R_3 of value $R_0/2$ to the lower half of the potentiometer as in Fig. 12, the network at the desired frequency ω_0 can be considered as a potentiometer consisting of two similar impedance arms connected across the voltage E_0 and the voltages E_0 and E_1 will therefore be in phase with each other at this frequency.

In the general case it can be shown that the correct value of R_3 is given by $R_3 = \left\{\frac{R_2 C_1}{R_1 C_1 + R_2 C_2}\right\} R_0$ which reduces to $R_0/2$ if the Cs and Rs are equal.

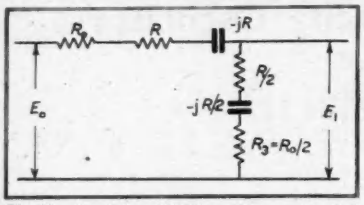


Fig. 12. $\omega_0 = 1/Rc$. **Addition of R_3 equal to $R_0/2$ brings E_1 in phase with E_0 at this frequency.**

Using such a resistance in the network it is entirely practicable to construct a resistance tuned oscillator which will follow any desired frequency law to a high degree of accuracy, certainly to 0.1% over a considerable frequency range. For example, let us suppose it is desired to construct an oscillator giving ten frequencies. The required resistances can be calculated, wound to the finest tolerance practicable and wired straight into the circuit. There is no need to trim any of the resistances because, even if the capacities are inaccurate the ten frequencies will all be in the right ratio and trimming the capacity to make one frequency correct automatically makes all the others correct as well. This applies equally well whether the number of frequencies is ten or ten thousand. Decade tuning is easily obtained by using a two gang decade conductance box for the resistances R and such tuning forms the basis of an oscillator which has been fairly completely described elsewhere.[15]

Practical Limitations

Phase Shift in Amplifier.— It has already been stated that the amplifier for the Willans oscillator should have a phase shift equal to zero or a multiple of 2π. It is necessary to consider the effect of unwanted phase shift on the frequency of oscillation, and it can easily be shown that in the case of an amplifier having small phase shift the frequency error is equal to 3/2 times the tangent of the amplifier phase angle, assuming that equal Cs and Rs are employed in the network. Thus, if the frequencies are desired to an accuracy of 0.1% the amplifier phase angle must not exceed $\tan^{-1}\frac{1}{1500}$. With the amplifier used to maintain the decade oscillator this condition was fulfilled over the range 500-20,000 c/s. Below 500 c/s. the phase shift becomes somewhat indeterminate owing to the presence of coupling and decoupling condensers and the frequency error can no longer be regarded as a small percentage although the frequency is normally correct to better than 2 c/s. down to very low frequencies. At the high frequency end of the scale it is normal to find an error of about 2% at 100 kc/s., but this error can easily be compensated by the use of a two gang trimmer condenser across the two tuning condensers. This trimmer can be of such a value as to give a total of 4% change in frequency when swung from minimum to maximum. It is calibrated so that when any particular frequency is set up on the decade dials and the trimmer is set to the appropriate mark the frequency is within 0.05%. The trimmer can also be used to give low frequencies accurately provided the frequency error due to unwanted phase shift or other causes does not exceed the trimming range.

In a normal resistance-capacity coupled oscillator the phase shift at the higher frequencies is of such sense as to cause the generated frequencies to be lower than their correct values. This tendency can be compensated to a certain extent by adjusting the resistance R_3 to be higher than its correct value, but if this process is carried to excess those frequencies at which the amplifier phase shifts are substantially zero will not decade properly, hence the trimmer condenser is usually necessary in oscillators going up to 40 kc/s. and over if high accuracy is desired.

Output Impedance of the Amplifier.— It has been shown that the effect of the amplifier output impedance on the frequency is cancelled out by the Resistance R_3. It is still desirable, however, for the output impedance to be low compared with the tuning resistance R in order to minimise the effect of changes in its value. In this connexion negative feed-back is of great value, although it should be emphasised that the effect of negative feed-back is only to reduce the output impedance and not to stabilise it. The type of amplifier which has been found most successful is shown in Fig. 13[7]:—

The negative and positive feed-back paths are both fed from the cathode of the third valve, a somewhat unconventional arrangement, but one with several advantages in practice:

(1) The output impedance looking into the terminals 1-2 is very low, of the order 10-20 ohms.
(2) The negative feed-back path is composed entirely of resistances, thus avoiding phase shift in this path over an extremely wide range of frequencies.
(3) The anode circuit of V_3 provides a very convenient point for obtaining output, since loading this circuit has a minimum effect upon the frequency of oscillation.

Reaction control can be effected by a potentiometer on the grid of V_3. The chokes L_1 and L_2 are included in order to reduce the amplifier phase shift at high frequencies.

Reaction Control.— If full advantage is to be taken of the 10,000 to 1 frequency sweep of the decade oscillator, manual reaction control is virtually a necessity, particularly if frequencies down to 1 c/s. are envisaged. Consequently, the practice has been adopted of providing a voltmeter across the output with a reference mark to which the output is adjusted when the frequency is changed. Over wide portions of the frequency range, particularly between 200 and 20,000 c/s. the reaction control can safely be left alone, but outside these limits adjustment may be necessary. Such adjustment not only ensures the greatest frequency accuracy, but also enables the harmonic content to be kept substantially the same at all frequencies. To those accustomed to high grade beat tone oscillators this reaction setting may appear somewhat cumbersome; as against this the actual frequency setting is delightfully simple. If the lowest and highest frequencies are not required

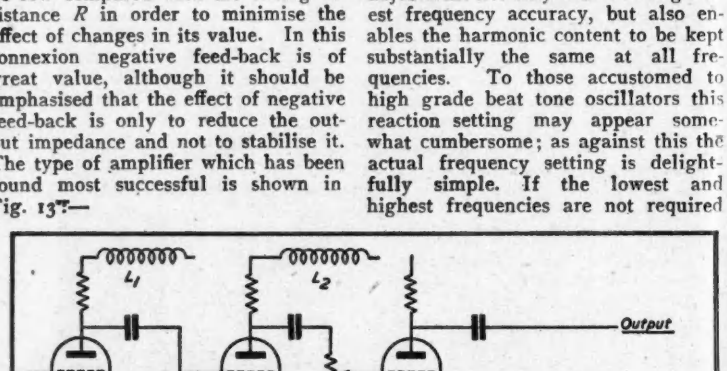


Fig. 13. Three stage amplifier suitable for decade oscillator.

the adjustable reaction control can be dispensed with altogether. This has been done in the case of oscillator 2 referred to in Table 1. In this oscillator, which has two ranges—100 to 4,000 c/s. and 1,000 to 40,000 c/s. the selection of the desired frequency is done simply by operating the range switch and setting the decade dials. The variations of output amplitude from 200 c/s. to 40,000 c/s. do not exceed ± 5%.

Practical Resistance Values for Tuning.—

With a four dial decade oscillator the highest resistance is ten thousand times that of the lowest so that some judgment is called for in selecting the optimum values. The value of the lowest resistance should, in the interests of stability, be fairly high compared with the output impedance of the amplifier; on the other hand, if this lowest resistance is made too high, difficulty may be encountered at the high resistance end. In practice a minimum resistance of 200 ohms has been found satisfactory, which leads at the other end to a maximum of 2 megohms. Using pairs of condensers, .08μF and .008μF, two ranges are obtained, one from 1 to 11,100 c/s. and the other from 10 to 111,100 c/s. The highest value of wire wound resistance employed is 100,000 ohms, which in the case of an oscillator going up to 10,000 c/s. corresponds to a frequency of 20 c/s. Above this value carbon resistors are employed, but even if these change their value by 4% the maximum effect this can have *at any frequency* is 0.8 c/s. and this only if the lowest value carbon resistance happens to be in circuit. If the oscillator has another range going up to 100,000 c/s. the maximum error would be 8 c/s., but the oscillator would not normally be used on the upper range below 10,000 c/s. consequently the error from this cause would be very small.

Performance Characteristics

Effect of change in supply voltage.—

It has already been pointed out that the output voltage of R-C oscillators is rather sensitive to changes in supply voltages. The decade oscillator is no exception to this rule, and in the case of one particular instrument it has been found advisable to derive the power supply from a saturated-core type voltage stabiliser. It has been found that the commercial saturated-core type stabiliser deals very effectively with amplitude variations in mains voltage, but unfortunately it is not proof against changes in mains frequency which produce corresponding variations in the stabilised voltage. Under normal peacetime conditions this would not matter very much, but nowadays, when the mains frequency may be at least 2% off the nominal, the effect is quite appreciable. In another more recently designed oscillator which is fitted with a simple form of A.V.C. and which is arranged to run off a vibrator power pack, a neon stabiliser only is used.

OSCILLATOR 1. A.C. operated through Saturated core type Stabiliser. Neon Stabiliser employed for H.T. Supply. 3 valve oscillatory circuit.				OSCILLATOR 2. Normal A.C. operation Neon Stabiliser employed for H.T. Supply. 2 valve oscillatory circuit employing A.V.C.			
Frequency C.p.s.	Mains volts Change %	Output volts Change %	Frequency Change %	Mains volts Change %	Output volts Change %	Frequency Change % Range 1	Frequency Change % Range 2
100	+10	+1	<+.005	+10	+4	+.08	
	−10	−1	<−.005	−10	−4	−.08	
1000	+10	<+1	<+.005	+10	+3	+.02	+.005
	−10	<−1	<−.005	−10	−5	−.02	−.005
4000	+10	<+1	<+.005	+10	+3	+.03	+.005
	−10	<−1	<−.005	−10	−3	−.03	−.005
10000	+10	<+1	<+.005	+10	+3		+.008
	−10	<−1	<−.005	−10	−3		−.008
40000	+10	<+1	<+.005	+10	+3		+.035
	−10	<−1	<−.005	−10	−3		−.035
100000	+10	<+1	+.005				
	−10	<−1	−.005				

The figures above tabulate variations of output voltage and frequency exhibited by two typical oscillators for ± 10% change in mains voltage.

Interpolation Accuracy

Apart from the overall frequency accuracy which defines the maximum error to be expected at any frequency setting, the interpolation accuracy to be expected over relatively small frequency variations is of great importance. For instance, a common problem is to measure the response of resonant circuits and filters. In such circumstances the oscillator can be standardised at a frequency within the filter band and the frequency additions and subtractions produced by varying the decade dials, can be relied upon to an accuracy which is better than the overall accuracy of the instrument. The table below shows the interpolation error of a decade oscillator used in this way. The oscillator was set accurately at two different frequencies, 15 kc/s. and 40 kc/s., and the frequency was varied in each case by ± 2,500 c/s., using the decade dials.

It will be seen from these tables that the maximum interpolation error is slightly above 0.05%, but for the vast majority of the settings it is considerably below this figure. The inaccuracy of interpolation is due more to the effect of stray capacities than to inaccuracies among the actual resistances, hence the error in terms of cycles per sec. is greater at high frequencies although the percentage error does not vary appreciably. If the highest possible accuracy is required it is desirable to tabulate over a band of testing frequencies the interpolation errors relative to one frequency in the band. If then the oscillator is standardised at that frequency to an accuracy of 0.01% it is quite possible to reproduce any of the other frequencies in the band to this degree of accuracy. This process can be repeated at any time regardless of the overall stability of the oscillator.

Frequency Stability

Regular checks have been made on

1. OSCILLATOR SET CORRECTLY TO 15 Kc/s.

Dial Settings (c.p.s.) 10,000	1,000	100	10	Error c/s.	Dial Settings (c.p.s.) 10,000	1,000	100	10	Error c/s.
1	5	0	0	0	1	5	0	0	0
1	5	1	0	+6	1	4	9	0	+3
1	5	2	0	+5	1	4	8	0	+3
1	5	3	0	+2	1	4	7	0	+3
1	5	4	0	+1	1	4	6	0	+4
1	5	5	0	0	1	4	5	0	+5
1	5	6	0	0	1	4	4	0	+5
1	5	7	0	0	1	4	3	0	+5
1	5	8	0	0	1	4	2	0	+7
1	5	9	0	0	1	4	1	0	+9
1	5	10	0	0	1	4	0	0	+3
1	6	0	0	−2	1	3	0	0	+5
1	7	0	0	−4	1	2	5	0	−1
1	7	5	0	−5					

The steps on the Tens dial are correct to better than 2 c.p.s.

2. OSCILLATOR SET CORRECTLY TO 45 Kc/s.

Dial Settings (c.p.s.)				Error c/s.	Dial Settings (c.p.s.)				Error c/s.
10,000	1,000	100	10		10,000	1,000	100	10	
4	0	0	0	0	4	0	0	0	0
3	9	9	5	−5	4	0	0	5	+8
3	9	9	0	−8	4	0	1	7	+10
3	9	7	8	−2	4	0	4	4	−8
3	9	4	3	+2	4	0	7	8	−8
3	9	2	5	+6	4	0	9	3	−12
3	9	0	0	+9	4	1	0	0	+24
3	8	9	1	−2	4	1	3	7	+15
3	8	4	5	+8	4	1	8	0	+5
3	8	2	8	+11	4	2	0	0	+12
3	8	0	0	+15	4	2	1	8	+15
3	7	7	7	+7	4	2	5	0	−7
3	7	5	0	+8					

a decade oscillator over a period of five weeks. During this time the nominal 100 kc/s. remained constant to ± 0.1% and the nominal 1 kc/s. remained constant to ± 0.05%. The stability over short periods of 30 minutes was about 0.01%. The maximum variation of room temperature while the test was being conducted was ± 5° C.

Effect of Changes of Valves on Frequency

A test involving changes of valves was made on a three valve oscillating circuit. Altogether 14 different combinations of valves were tried. The greatest observed differences in frequency were 0.1% at 1,000 c/s. and 0.2% at 50 kc/s. It was noticeable in this case that the first valve was the one having the most effect on the frequency. It is invariably found that one valve has more effect than the others, the reason being that the amplitude of oscillation must necessarily be limited by the curvature of valve characteristics, however slight, and such limiting occurs first in one valve. The question of the effect of different valves on the frequency is bound up with thermionic conditions and no two oscillators will exhibit identical behaviour in this respect. From observations of a number of oscillatory circuits, however, it can be stated that the change in frequency resulting from substituting one valve for another is unlikely to exceed 0.4% at 50 kc/s. and will be less at lower frequencies. Any normal change of calibration resulting from changes of valves, temperature effects, supply voltage variations, etc., can be easily compensated by an adjustment described below.

Method of Resetting Calibration

The changes of calibration experienced in practice are of two kinds: (1) Changes which mainly affect higher frequencies, and (2) changes which affect all frequencies, to an equal degree. Those of the first kind appear as though they were caused by variations in the amplifier output impedance and can be compensated by re-adjusting the resistance R_3, which is normally made semi-variable. Those of the second kind appear as though they were caused by variations in tuning capacity and can therefore be compensated by adjusting a two gang trimmer condenser C_T shown in Fig. 14.

It is found in practice that with the aid of these two controls any changes in the decade calibration due to variations of temperature, changes of valves, etc., can be taken up and the calibration can be restored to within .025% of its original accuracy provided the tuning resistance values have not altered relative to each other.

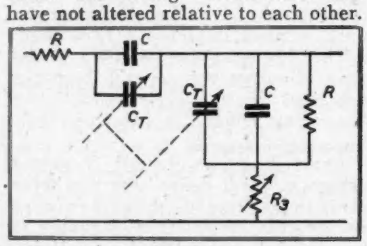


Fig. 14.

The process of re-adjustment for a complete calibration using a cathode ray oscillograph and a frequency standard takes about five or ten minutes.

Conclusions

Oscillators employing resistance-capacity networks exhibit good frequency stability and good waveform over a considerable range of frequencies provided the amount of reaction employed is not excessive. It is desirable in the interests of frequency stability that the networks employed should be fed from a source of low impedance and terminated by a high impedance. The decade principle described makes possible the design of a frequency generator of high accuracy for audio and low carrier frequencies. Its outstanding feature is that the frequency is made direct reading without the complexity or inevitable loss in setting accuracy which occurs in all other types of oscillators. Subsidiary features are its wide range of frequency, ease and accuracy of frequency interpolation, good waveform over the whole range and the readiness with which the calibration can be restored to its original accuracy after valve or component changes.

Appendix

It would appear that resistance-capacity networks might have possibilities in certain measurements not easily carried out at present, in particular measurements of phase shift and output impedance of amplifiers. Thus, if a suitable R-C network is connected between input and output of an amplifier, and the system is made to oscillate it is possible to calculate the amplifier phase shift from the frequency generated and the R-C constants. For example, the phase shift of the amplifier shown in Fig. 14 is known to lie within certain limits because of the accuracy of the frequencies generated by the system as a whole. Similarly, it is possible to work out methods by which the amplifier output impedance can be evaluated using a similar technique. Measurements of this type would have to be interpreted with some care, but it is suggested that they might lead to improved accuracy in certain cases because the quantity which is actually measured, *i.e.*, frequency, is capable of determination to a high degree of accuracy.

Bibliography

1 B. Van der Pol and J. Van der Mark, British Patent No. 395,596, July 20th, 1933.
2 H. W. Nichols, U.S. Patent No. 1,442,781, January 16th, 1923.
3 E. L. Ginzton and L. M. Hollingsworth, "Phase Shift Oscillators," *Proc. I.R.E.*, Vol. 29, February, 1941.
4 F. M. Colebrook, "A New Circuit for Resistance Tuning," *Wireless World*, Vol. 36, February 8th, 1935.
5 P. W. Willans and N. L. Yates-Fish, British Patent No. 489,849, August 4th, 1938.
6 P. W. Willans, "Resistance-Capacity Tuning," *Wireless World*, Vol. 44, January, 5th 1939.
7 P. W. Willans, British Patent, No., 497,148. December, 1938.
8 F. E. Terman, R. R. Buss, W. R. Hewlett and F. C. Cahill, "Some applications of negative feedback with particular reference to laboratory equipment," *Proc. I.R.E.*, Vol. 27, October, 1939.
9 Paul S. Delaup, *Electronics*, Vol., 14, January, 1941.
10 Stanley R. Jordan, "The Controlled Transitron Oscillator," *Electronics*, Vol. 15, July, 1942.
11 Wayne B. Nottingham, "R.C. Oscillator Analysis," *Electronics*, Vol. 15, July, 1942.
12 H. H. Scott, "A new type of selective circuit and some applications," *Proc. I.R.E.*, Vol. 26, February, 1938.
13 C. E. Lockhart, "Tuned Amplifiers," *Electronics and Television and Short-Wave World*, Vol. 18, May, 1940.
14 E. R. Wigan, British Patent No. 524,314, August 2nd, 1940.
15 "A New Frequency Generator," *Electronic Engineering*, June, 1941.

Corrections to Part I

In Part 1 of this article it is regretted that a typographical error occurred in the equations for frequency.

For $\frac{1}{2\pi\sqrt{3CR}}$ read $\frac{1}{2\pi\sqrt{3CR}}$.

and $\frac{1}{2\pi\sqrt{6CR}}$ read $\frac{1}{2\pi\sqrt{6CR}}$.

Laminated Wood as an Insulator

By A. E. L. JERVIS, A.M.I.E.E.*

THE study of wood insulation has received less attention than most other forms of insulation.

The purpose of this article is, therefore, to record some of the principal characteristics of the laminated densified wood used in electrical apparatus and also of the existing and some of the possible applications.

Although ordinary low-pressure plywood would seem to have been made in this country for forty years and high-pressure electrical plywood for twenty years, it has really taken a second World War to stimulate general interest in the possibilities arising from the manipulation of very thin slices of wood in packs subjected to intense pressure and considerable heat.

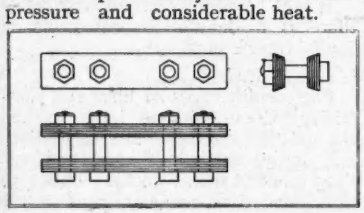


Fig. 1. Rail fishplates of laminated wood.

The chief factor perhaps in bringing improved laminated wood to the public notice is its use in the Mosquito aeroplane. Its use in other applications is perhaps known in the following order of importance :—

(1) Propeller blades and fans.
(2) Electrical insulators.
(3) Aircraft tools.

New applications appear from time to time, one recent example from America being particularly striking. The following is quoted verbatim from *The Times Trade and Engineering Supplement* for September :—

Laminated Boards

" Great progress has already been made during the war, particularly in the United States, in the science of wood fabrication. Laminated boards from fifty to nearly a hundred feet in length and over two feet in width can now be produced.

In fabricating them, boards of ordinary length are reduced to thin laminations, scarfed at the ends to ensure a perfect join with the corresponding lengths at either end and then bonded and compacted into homogeneous wood by means of waterproof glue and heavy pressure. In this way boards of any desired length, breadth or thickness, curved or straight, can be produced.

In some of the drill-halls erected in the United States since the war there are laminated arches over a hundred feet in width which give a clear span without the need of any additional support, yet carry a combined weight and pressure of nearly a hundredweight per square foot of roof surface.

This development is important to the home-grown timber trade of the United Kingdom, for the drawback of the limited length and girth of the native logs can be overcome by skilful fabrication and lamination."

Considered purely from the commercial angle, the first point which strikes one is whether the increased popularity brought about by the war will disappear with what someone has called " The Outbreak of Peace." On the other hand, it can be argued that as modern synthetic resins do not encourage the growth of fungi, as did the original glues, pre-war objections to plywood arising from unsuitable glues will disappear now that excellent synthetic resins are available.

During the last year or two, the author has been privileged to witness numerous tests on laminated wood, and as there do not appear to be any electrical books on the subject (apart from the excellent brochure issued by the New Insulation Co., and informative leaflets by Moulded Components (Jablo) Ltd.) he investigated all sorts of applications, some novel and some quite old. Many of the tests only substantiated characteristics already well known to many manufacturers. A bibliography is given at the close of this article. The author apologises for including so many references to his own articles, but published data on resin-impregnated wood during recent years, has, in the English Press, been almost exclusively confined to the articles covering the research of Moulded Components (Jablo) Ltd.

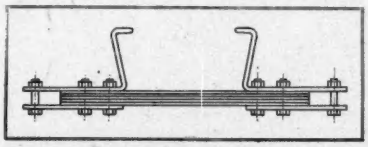


Fig. 2. Typical arrangement of stay-rod and arcing-horns with laminated wood insulation.

In this article are given some average values for laminated densified wood taken from the trade publications and articles which have appeared somewhat infrequently during the last few years. In addition, in Table 1, they are contrasted with those of porcelain and laminated paper and fabric boards. The figures for porcelain are taken from Dr. Rosenthal's book, " Porcelain and other Ceramic Materials," shortly to be published by Messrs. Chapman & Hall.

The most striking characteristics of laminated densified wood are its tensile strength and its strength in bending, in both of which respects porcelain is not so good. Unlike porcelain, it can be dropped without danger of cracking.

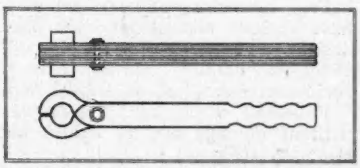


Fig. 3. Laminated wood H.T. fuse extractor

It must be conceded, however, that there are drawbacks to laminated wood but, of course, many of these can be overcome. For example, certain types will absorb 25 per cent. of their own weight of water and moreover, expansion is not the same in all directions. Other insulating materials have corresponding drawbacks.

Applications of Laminated Wood

To illustrate the versatility of bakelised wood,* sketches are given showing the following :—

(*a*) Fish-plate for electric railway tracks.
(*b*) Fuse extractors.
(*c*) Radio interference spindle.
(*d*) Stay rod to meet the relaxed Overhead Line Regulations.

* Late of Moulded Components (Jablo) Ltd.

* ' Bakelised wood ' is used here as a convenient brief term for ' resin impregnated laminated wood '. The term ' bakelised ' is proprietary to the Bakelite Co.—Ed.

TABLE I
Porcelain compared with Laminates

	Laminated Wood	Porcelain	Laminated Paper/Fabric
Tensile Strength (10 lbs./sq. in.)	18—50	4—6	7—18
Compressive Strength (10 lbs./sq. in.) ...	10—30	64—78	21
Bending Strength (10 lbs./sq. in.) (Modulus of Rupture)	10—30	4—14	21

In the first place it is very doubtful whether there is any other form of plastic available which meets the above applications as well as bakelised laminated wood, and so a few remarks may be of interest.

(*a*) *Fish-plates.*

These are produced by several firms, but perhaps the best known in this country is the " Permali " Plate manufactured by the New Insulation Company. It is claimed that track circuit-block joints made from bakelised wood combine simplicity with high electrical efficiency and that it is impossible for a signal fault to occur through failure. Moreover, they are a much simpler job than steel wrapped in fibre and similar devices. (Fig. 1.)

(*b*) *Fuse Extractors.*

Outdoor and indoor switch operating rods of bakelised wood are well known, but fuse handling devices of bakelised wood are not generally available.

Fuse extractors of bakelised wood have definite advantages over other designs and are more " foolproof." Porcelain handles usually chip if accidentally dropped on a hard floor.

Bakelised wood can be dropped without damage and is lighter and stronger. (Fig. 3.)

(*c*) *Radio Interference.*

Raising of the Radio Interference point of porcelain pin-type insulators by using laminated densified wood spindles is very interesting (Fig. 4).

In spite of the introduction of new designs, the orthodox type of pin insulator with steel spindle has held its own right from the inception of overhead transmission lines. Where, however, operating conditions and industrial deposits are of an abnormal or unusual character, then an alternative to the pin insulator and steel spindle combination may be an advantage. This is because the voltage distribution is extremely bad, owing to the fact that the earthed steel spindle is brought within, say, one inch of the overhead line conductor. (Where the " earth " is kept a long distance away from the overhead conductor, as in the case of the Line Post type of insulator, the voltage distribution is to all intents and purposes ideal.) If the steel spindle is replaced by a laminated wood spindle the earth is kept a long distance away from the overhead line conductor and the voltage distribution is improved.

With irregular voltage distribution certain parts of a pin insulator are over stressed and it has been found that deposits form most thickly on the over-stressed parts. Gradually portions of the porcelain surface are short-circuited, other portions are over-stressed, until finally " sparking " occurs causing radio interference and eventually leading to complete breakdown of the insulator.

Table 2.
RADIO INTERFERENCE.

Normal Working Voltage	11 kV		35 kV	
S.O.V.—Spark-over	Wood Spindle	Steel Spindle	Wood Spindle	Steel Spindle
S.O.V. Dry kV	70	68	157	157
S.O.V. Wet kV	50/55	44	120/125	116
Radio Interference kV	14	8.5	24	15

With an insulated spindle, radio interference takes place at a much higher voltage, as will be seen from the Table 2.

It will be noted that in both cases there is a definite improvement in Radio Interference values.

(*d*) *Stay Rods.*—

For certain types of lines the Electricity Commissioners have relaxed the existing overhead line regulations and permit the use of unearthed pole lines (bonded metal work). This type of construction, however, involves the use of heavy duty insulators in the stay wires stretched from the top of the pole to the ground. Fig. 2 shows a typical arrangement of stay rod and arcing horns, which are intended to pass lightning surges through to earth. To date, it has been customary to use imported woods such as karri and gurjun which, when drilled, have a breaking strength of only approximately 4,000 to 6,000 lbs. per square inch. As drilled laminated wood has a breaking strength of 10,000 to 12,000 lbs. per square inch, it is possible to evolve a much smaller and neater stay insulator and metal end fittings.

The requirements of insulated stay rods are :—

(*a*) To take the full ultimate strength of the stay wire.
(*b*) That there shall be a minimum of shrinkage or distortion in service.
(*c*) That the insulators shall have satisfactory impulse and leakage characteristics under all weather conditions.
(*d*) The insulators shall be as fire-proof as possible.

Unfortunately, at the moment, some kinds of laminated wood are somewhat dearer than the more expensive natural timbers (certain plywoods can of course be cheaper). If, however, the development of cross-jet-propelled aircraft reduces the demand for aircraft propellers this may set free more presses for the manufacture of other

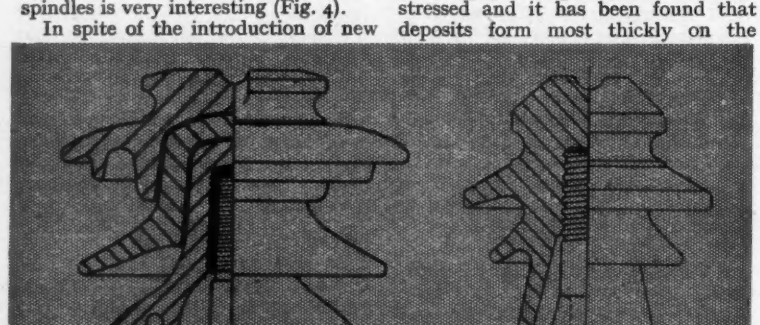
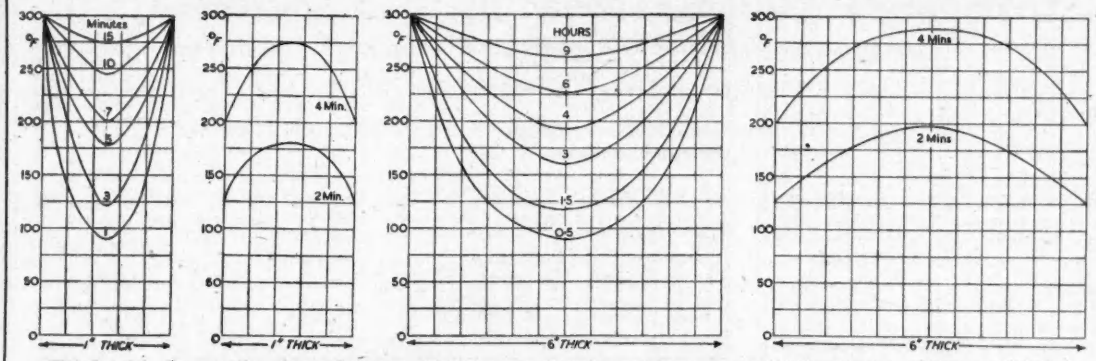


Fig. 4. The use of laminated wood spindles in porcelain insulators minimises radio interference. (Left) typical 33 kV insulator. (Right) typical 11 kV insulator.



Figs. 5 and 6. Comparative curves of steam and high frequency heating. (Left) steam and H.F. heating for a thickness of 1 inch. (Right) steam and H.F. heating for a thickness of 6 inches. *(After Taylor).*

Fig. 7. Variation of Power Factor with moisture content. (1) Maple, (2) Mahogany, (3) Spruce. *(After Taylor).*

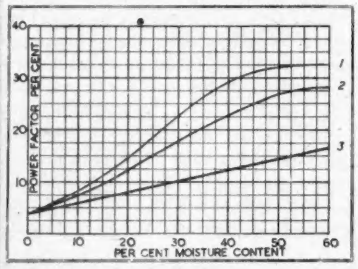


Fig. 8. Variation of dielectric constant with moisture content. (1) Maple, (2) Mahogany, (3) Spruce. *(After Taylor).*

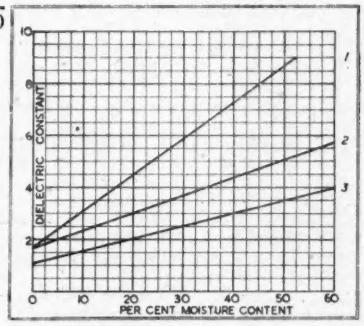
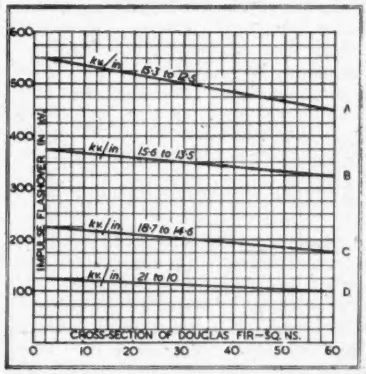


Fig. 9. Impulse Flashover of four lengths of wood rods of varying cross sections.



components at slightly more favourable prices.

Impulse Data

As there appears to be little, if any, published data on the behaviour of bakelised wood under impulse testing the following details may be of interest.

Fig. 11 illustrates a simple rod of resin impregnated wood with binding wire electrodes and gives values for impulse flashover under oil for varying distances. Flashover under oil is usually accompanied by partial "delamination" of the veneers. The data given does not refer to all cross sections of rod.

It will be noted that the flash-over value per inch appears to decrease with increasing cross section of bakelised wood.

In this connexion the reader is referred to Messrs. Sporn and Lusignan's paper, "Lightning Strength of Wood in Power Transmission Structures,"[3] from which Fig. 11 is taken. They state:

"The impulse flash-over value of wood insulating members is affected by the cross-sectional area of the wood, being, in general, lower the larger the wood section. The factors producing this result are not well understood and the subject should be further investigated."

High Frequency Heating

No article dealing with laminated densified wood is complete without a reference to the high frequency method of heating laminated wood during the pressing operation. The two main advantages of high-frequency heating are:

(1) Speed.
(2) Uniformity of heating.

To illustrate (1) Figs. 5 and 6, taken from J. P. Taylor's paper,[4] shows the comparison between steam heating and high frequency heating. In the case of (2) it is obvious that, when laminated wood is used as the dielectric of a condenser, the heat is generated internally. When steam-heated platens (or platens heated electrically by 50 c/s. current) are used it may take several hours for the heat to reach the centre of the pack. The result is that the outer layers are "cooked" more than the inner layers.

Calculations

When the specific gravity and specific heat of the wood laminations are known, it is easy to calculate how many calories are needed in order to cure a given volume of the material. Fig. 10 gives watts necessary per cubic inch.

Frequency and Voltage

Calculation of suitable voltage for handling a 1 ft. cube of Laminated Wood.

In the following example (based on J. P. Taylor's paper) a frequency of 1 Mc. is assumed.

$$\text{Capacity (Farads)} = \frac{8.85 \times 10^{-14} \times \text{K.A.}}{d}$$

where K = Dielectric Constant (say 5)

A = Area in sq. cms. $= 12 \times 12 \times 2.54^2$

d = Thickness in cms. $= 12 \times 2.54$.

$$\frac{\text{K.A.}}{d} = \frac{5 \times 12 \times 12 \times 2.54 \times 2.54}{12 \times 2.54} = 152.4$$

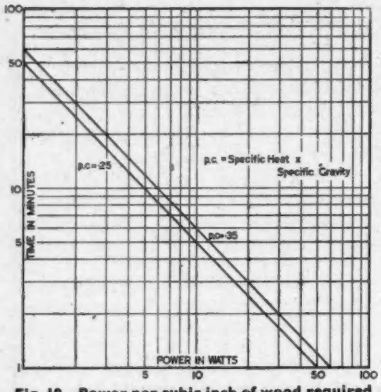


Fig. 10. Power per cubic inch of wood required to raise temperature 320°F. against time.

Capacity of 1 ft. cube

$$= \frac{8.85 \times 152.4}{10^9} = 13.5 \text{ pF.}$$

$$\text{Reactance } X_c = \frac{1}{2\pi fc} = \frac{10^{12}}{2\pi 10^6 . 13.5}$$

$$\simeq 11.8 \times 10^3 \text{ ohms.}$$

$$\text{Equivalent Resistance } R_p = \frac{X_c}{\text{P.F.}}.$$

Assuming Power Factor to be 0.05,

$$R_p = 20 \times 11.8 \times 10^3 = 2.36 \times 10^5 \text{ ohms.}$$

Assuming that the resin is cured in four minutes, and that the power required per cubic inch is 20 watts, then power required per cubic foot

$$= 20 \times 1{,}728 = 3{,}456 = i^2 R_p.$$

$$\text{Current } i_r = \sqrt{\frac{3{,}456}{2.36 \times 10^5}}.$$

$$= \sqrt{.0146} = 0.122.$$

$$\text{Voltage } (E)\ i_r R_p\ 0.12 \times 2.36 \times 10^5 = 28{,}320.$$

Apparently voltages in excess of 15 kV are not advisable for various reasons, such as the appearance of corona trouble, etc.

If the calculations are repeated for a frequency of 10 Mc./s., the required voltage is 9 kV.

Laminated Wood Characteristics—Variation

A feature of the available literature on the subject is the wide variation in characteristics attributed to laminated wood by different authorities.

Table 3 gives an approximation of published data, within the range of which good quality wood characteristics should fall.

Mechanical	
Specific Gravity	0.9 to 1.4
Weight (lbs./cu. ft.)	56 to 87
Ultimate Tensile Strength (lbs./sq. in.)	18,000 to 50,000
Compressive Strength (lbs./sq. in.)	10,000 to 30,000
Shear Strength (lbs./sq. in.)	3,000 to 20,000
Modulus of Rupture in Bending (lbs./sq. in.)	10,000 to 30,000
Janka Hardness Figure	8,000 to 10,000
Water Absorption (%) (24 hrs.)	1 to 15
Water Absorption (%) (7 days)	2 to 25
Electrical (at 50 c/s.)	
Breakdown, along Laminæ (20° C/volts/mil.)	13 to 40
Breakdown, along Laminæ (90°C/volts/mil.)	10 to 30
Breakdown, through Laminæ (20°C/volts/mil.)	100 to 200
Breakdown, through Laminæ (90°C/volts/mil.)	130 to 150
Dielectric Constant (Permittivity)*	4 to 5
Loss Angle (Power Factor)*	0.04 to 0.06
Volume Resistivity 10^6 Megohms./cm.^{3}	1
Surface Resistivity—60% Humidity (10^4 Meghoms./cm.^{2})	4 to 5
Surface Flashover in Air—60% Humidity (kV/in.)	10 to 18
Surface Flashover in Oil—20°C. (kV/in.)	50 to 70
mpulse Flashover under Oil (20°C. (kV/in.)...	50 to 100

* Measured on Schering Bridge at 10 kV.

TABLE 3. Approximate Characteristics of Laminated Wood

REFERENCES:

1 Tech des Holzes, Kollman, Berlin, 1936.
2 P. Sporn and J. T. Lusignan, Lightning Strength of Wood in Power Transmission Structures, *Trans. A.I.E.E.*, Vol. 57, (1938), p. 91.
3 Elektrischie Machnichtentechn, Vol. 12, (1935).
4 J. P. Taylor, Heating Wood with R.F. Power, *Trans. A.S.M.E.*, Vol. 56, (1934), p. 201.
5 High Frequency Heating, *Aircraft Production*, Vol. 5, (1943), p. 402.
6 M. Finlayson, High Density Plywood, *Trans. A.S.M.E.*, Vol. 65, (1943), p. 193.
7 Heating Thick Laminated Boards, *Electronics*, Vol. 15, (1942), p. 79.
8 W. Godfrey and P. H. Bilhuber, High-frequency Gluing of Resins, *Modern Plastics*, Vol. 21, (1943), p. 89.
9 V. E. Meharg, Heatronic Molding, *Modern Plastics*, Vol. 20, (1943), p. 87.
10 H.F. Heating for Plastics, *British Plastics*, Vol. 15, (1943), p. 322.
11 A. E. L. Jervis, Laminated Densified Wood, *Electrical Review*, 27/3/1942, p. 395.
12 A. E. L. Jervis, Insulating Wood, *Electrical Review*, 6/11/1942, p. 581.
13 A. E. L. Jervis, Characteristics of Bakelised Wood, *Electrical Times*, 15/4/1943, p. 428.
14 A. E. L. Jervis, Densified Laminated Wood for Jigs, *Machinery*, 17/12/1943, p. 673.
15 A. E. L. Jervis, Resin Laminated Densified Wood, *Plastics*, Vol. 7, (1943), p. 122.
16 A. E. L. Jervis, Synthetic Resin Laminated Wood Insulation, *British Plastics*, Vol. 15, (1943), p. 223.
17 R. Casselman, Resin Impregnation of Wood, *Mechanical Engineering*, Vol. 65, (1943), p. 737.

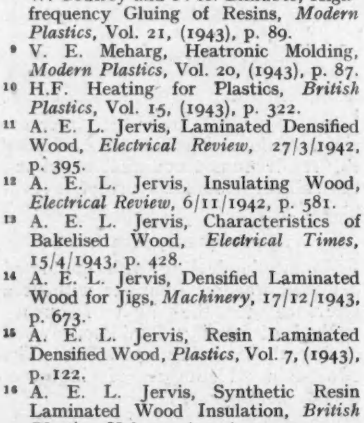


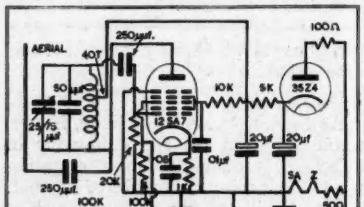
Fig. 11. Impulse Flashover of rods. (After Sporn & Lusignan.)

Oscillator for Gramophone Records

A compact oscillator for reproduction of records by modulation of a 1,500 kc/s. note is described in *Radio Craft* for August, 1943, by W. Embree.

The circuit is assembled on a chassis measuring only 5 in. by 2⅛ in. by 1¼ in. high, and the components need careful packing to enable them to be fitted in the space.

A 35Z4 is used as a rectifier and a 12SA7 as an oscillator, the heaters being in series with a 500 ohm resistor across the supply. The resistor should be mounted above the chassis if the unit is to be operated for long periods.



The oscillator coil is wound on a ½ in. diameter tube, 1 in. long the length of the winding being ½ in. of No. 40 enamelled wire* (140 turns tapped at 100 turns).

For tuning a 25-75 μμF padding condenser is used in parallel with a 50 μμF mica. The author noted distortion when the frequency was below 1,300 kc/s.

The aerial was made from a piece of ⅛ in. rod 10 in. long, bent to run round the top of the chassis, and parallel to the top at a distance of 1 in. above it.

* 40 B. & S. = 44 S.W.G. approx.—Ed.

The Recording of High Speed Transient Phenomena

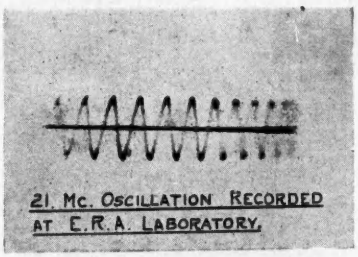
by the Hot Cathode, Glass Bulb, Cathode-Ray Oscillograph

By W. NETHERCOT,* M.A., B.Sc.

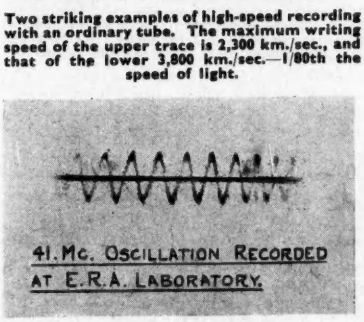
A Lecture delivered before the Association for Scientific Photography at the I.E.E. on Saturday, November 13th, 1943.

THE cathode-ray oscillograph is an instrument essential to the investigation of high speed transient phenomena which are non-recurring or which recur at irregular time intervals. There are two types of oscillograph, the high voltage continuously evacuated type in which the record is obtained by the electron beam impinging directly on a sensitised plate or film, and the lower voltage hot cathode, sealed off glass bulb type with fluorescent screen. This emits light when the electron beam falls upon it and the record is obtained by external photography. The glass bulb oscillograph has many advantages. The beam accelerating voltage is usually between 5 and 10 kV. and so the complete equipment can be built into a comparatively small space. It is readily transportable and can be used in places and under conditions not suited to the continuously evacuated type. The relatively large fluorescent screen is very convenient for visual work and the external photography saves considerable time and trouble as there is no need to insert a photographic film into a vessel which has to be highly evacuated. To do this one has to introduce air into a large part of the apparatus until it reaches atmospheric pressure, insert the film and then pump out the air until the requisite vacuum is obtained. This is an irksome process which becomes highly irritating if leaks develop round the vacuum seals.

The difficulty with the glass bulb oscillograph is to attain really high writing speeds or at least high writing speeds that can be recorded. In case any of you are not familiar with this term, I should explain that it denotes the velocity of the electron beam across the film or screen and is usually expressed in kilometres per sec. Apart from the fact that the current and velocity of the electron beam are much smaller than in the continuously evacuated oscillograph, the external photography imposes a serious limitation from the speed point of view. With an efficient glass bulb oscillograph, traces of very high speed can be seen on the screen if it is viewed through a viewing hood or in a darkened room, but the difficulty is to photograph them and so obtain a permanent record for analysis and measurement. However, a great deal can be done by careful attention to the photographic technique and I hope to show that it is possible to attain writing speeds in the range normally associated only with the continuously evacuated oscillograph. The work I am going to describe was carried out in collaboration with Mr. Beattie, who is in charge of the photographic section of the E.R.A. I am also greatly indebted to the technical staffs of Messrs. Kodak and Ilford for their advice and assistance.



Two striking examples of high-speed recording with an ordinary tube. The maximum writing speed of the upper trace is 2,300 km./sec., and that of the lower 3,800 km./sec.—1/80th the speed of light.



There are various forms of fluorescent screen, the one most suited to photographic recording is that which gives a blue or blue-violet trace. My remarks are therefore confined to this type of screen. Now in single transient recording the electron beam traverses the screen only once. The exposure time of the film is therefore determined solely by the duration of the fluorescent glow from the screen. The film is exposed to the screen some time before the arrival of the transient; with uncontrolled transients the time may be quite long. This introduces complications about which I shall have more to say presently. In recording transients of very short duration the time taken by the electron beam to traverse the screen may be only a fraction of a microsecond. The screen, however, emits light for a much longer time than this on account of the afterglow although the intensity decreases rapidly after the beam has traversed the screen. There are two ways of photographing the trace on the screen, one by direct contact of the film with the screen and the other by a lens camera.

The first method is simple, but has so many disadvantages that it has only a very limited application. In the first place the operation must be performed in the dark, and this is often an insuperable obstacle. As the fluorescent screen is on the inside of the glass which has to be fairly thick for mechanical strength, the light rays from the trace have diverged considerably by the time they reach the film. This means that even the finest of traces records as a thick line. For transients of simple wave shape, this may not matter, but it does not allow sufficient resolution when the trace contains lines which are close to each other. Also most oscillograph screens are convex in shape, the curvature increasing rapidly towards the edge of the screen. Therefore the film is not in intimate contact with the glass except over a small central area.

Fig. 1 shows two negatives made by direct recording. The top record is of the 1 microsecond timing wave which the operator can generate from the time sweep, the bottom one is of a 6 Mc/sec. external oscillation with a single time sweep. They illustrate quite clearly the limitations of this method of recording. The lens camera is therefore the only satisfactory method of recording. If the records can be taken in a dark room then a normal type of camera can be used provided it is fitted with a lens of adequate speed. The camera must also be able to focus on an object near to the lens as otherwise the record obtained of a trace on, say, a 6 in. diameter screen will be impossibly small. It is much better if the camera is built for the job, in which case it should be attached to the oscil-

* E.R.A. Research Labs.

lograph by a light-tight hood. For visual work the camera itself may be swung aside on a hinge or the hood may be provided with a light-tight viewing flap. With this arrangement one can work in normal light, in fact, on many occasions I have recorded out of doors in bright sunlight. I think it is desirable that the camera should be equipped for both slides and a roll film adaptor. Sometimes it is necessary to check each record as it is taken; at other times it may be more convenient to take a series of records and economise in time by a single development.

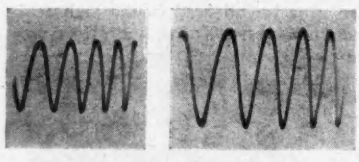
The choice of a lens is a compromise between its speed, cost and the size of the picture that can be taken with it. Under present conditions there is also the supply problem. Of the lenses in the possession of the E.R.A. a number of cine camera and projection lenses were available to me. Some were of 2 in. focus with an aperture ratio of 1.9, the others were 1 in. focus with aperture ratios ranging from 1.9 to 1.4.

Now, to obtain a negative of reasonable size and to keep the camera attachment from becoming too bulky the lens has to be near to the oscillograph screen with consequent reduction of its depth of focus. The oscillograph screen being curved, there must inevitably be distortion and defocusing of the trace at its edge, especially as the maximum curvature occurs there. Over the centre of the screen the curvature is comparatively small. The electrical characteristics of cathode-ray tubes are such that maximum distortion and defocusing of the beam occur when it is at the edge of the screen, so as far as possible I arrange for that part of the transient in which I am especially interested to fall within the central area of the screen. For instance, on a 5½ in. screen a useful working area is about 4 in. in diameter.

The negatives obtained with the 1 in. focus lenses were satisfactory except that they were rather too small with the result that the definition was lost when they were enlarged to the size demanded for measurement or reproduction. With the 2 in. focus lenses one can obtain negatives of workable dimensions.

Fig. 2 shows the conditions obtained with a 2 in. focus *f* 1.9 cine lens. Here the negative sizes are about ¾ in., 1 in. and 1⅜ in. Both of these lenses give quite good focusing with object distances down to 8 in. or 9 in., but the intensity of the trace tails off somewhat at the edges. This is more marked at the smaller object distances. The reason for this is that the intensity of the light from any point on the screen is a maximum in the direction normal to the screen and a minimum when the direction is tangential to the screen at that point. Now at the edge of the screen that part of the light which meets the lens is emitted at an appreciable angle to the normal and this angle is increased considerably by the increasing curvature of the screen towards the edge. This is shown clearly in Fig. 3 which contains negatives of a 6 Mc/sec. oscillation recorded with the 2 in. focus *f* 1.9 lens. Here the trace is much weaker as the maximum writing speed has risen to 450 kilometres per sec. The thick black line is a 1 microsecond timing wave generated within the oscillograph. This is the lens that I have used for high speed recording and I have found the best all round results are obtained with an object distance of between 8 and 9 in. The 1 in. focus lenses, however, have been very useful when it has been necessary to record a series of irregularly recurring transients in which the time intervals between successive transients is long compared to the duration of the transient. In this case a moving film camera is used, the speed of the film being such that it can be considered stationary as far as the transient is concerned, yet fast enough to prevent overlapping of the records. The small size of the record is a convenience here as the length of the film used is thereby reduced.

Fig. 1. Two negatives made by direct contact, showing the limitations of this method of recording.



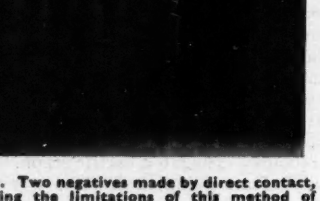


Fig. 2. Three negatives of an 80 kc./sec. oscillation taken with a 2 in. focus f 1.9 lens at object distances of 12 in., 9 in., and 7½ in.

Recently, through the courtesy of the Kodak Research Department, I have been able to make some tests with a 2½ in. focus *f*.1 lens constructed by Taylor, Taylor and Hobson for radiography. The glass surfaces of this lens are coated to reduce reflection losses. Its speed is considerably greater than the *f* 1.9 lens and this is demonstrated in the next slide.

Fig. 5 shows two negatives of a 6 Mc/sec. oscillation; the top one is with the *f* 1.9 lens and the bottom with the *f*.1. In both records the light intensity of the trace, the film and the development are identical and the object distances are approximately equal so that the different image densities are a measure of the relative speeds of the two lenses.

I believe that the *f*.1 lens is very expensive and the cost of an oscillograph camera equipped with such a lens would be a large proportion of that of the complete oscillograph. As far as I know, no lens has yet been designed specifically for high speed cathode-ray recording, but it seems to me that if this were done it might be possible to introduce simplifications in design which should reduce the cost considerably. I have already stated that the oscillograph screens for high speed photography give a blue trace. As I have not examined the light spectroscopically, I cannot say that all of it is concentrated into the blue or blue-violet band of the spectrum. The appearance of the trace suggests that this might be so and if this is the case then the lens would need no chromatic correction, or, at least, less correction than for the normal camera lens. This would considerably simplify the construction and would reduce the losses due to surface reflection and glass absorption. I also think that the other corrections applied to the high grade camera lens may be unnecessarily stringent for this class of work. For instance, the lens is required to work with a fixed object distance, and the resolution demanded of it is not very high as the films of extreme speed which have to be used determine the

limitation in this respect. However, presupposing a lens, specifically designed for oscillograph recording, it would be of great advantage if a correction could be made for the curvature of the screen as there is no depth of focus with a large aperture lens at very short object distances. The speed of the photographic emulsion is obviously of first importance. The speed figures given in the catalogues of the film manufacturers are based usually on the response to daylight or half-watt lighting and are not always a reliable guide in selecting the material with the highest performance for this work. Of course, they enable one to discriminate between fast and slow films, but not necessarily between, say, a panchromatic and an orthochromatic emulsion whose speed figures are equal or nearly so. We have found that certain orthochromatic emulsions give the best all round results, so far we have found nothing superior to the Ilford 5.G.91 and the Kodak R.55 films. I have recorded traces of very high writing speed with Kodak Ortho X film, but it is not as fast as the other two. As a general rule no advantage is to be obtained by using panchromatic emulsions. I have found only one whose speed exceeds that of the 5.G.91 and the R.55 films. There are some serious drawbacks to the high speed panchromatic emulsions. In the first place the cameras must be loaded and the films developed in complete darkness. This can be very inconvenient with some types of moving film camera. It is also a nuisance when one has to develop in unfamiliar or improvised dark rooms. When using orthochromatic emulsions one can use a small portable red safelight and this is a great convenience. Another drawback is that the red glow of the hot cathode is often visible through the screen. The light from the cathode passes through the hole in the first anode and a pencil of rays strikes the screen at its centre. With high speed panchromatic emulsions this produces a circular area of fog at the centre of the record even when the camera shutter is opened only for the minimum time to enable the transient and the various calibrating traces to be photographed. This time may be only 2 or 3 seconds, but it is long enough to fog the film. When the film has to be exposed to the screen for an appreciable time before the arrival of the transient as may happen when trying to record surges on overhead power lines, a panchromatic film would become hopelessly fogged. Even if emulsions are used which are not red sensitive it is essential in this case to use a camera with a slowly moving film. Two possible methods of eliminating this effect are to use a blue filter in front of the lens and to incline the camera at an angle to the screen so that the light from the cathode misses the lens. The first method cuts down the light intensity and so removes the one advantage the panchromatic emulsion may have over the orthochromatic emulsion. With the cathode-ray tubes which I have used the angle through which the camera has to be turned is great enough to throw the negative well out of focus. So unless it is essential to obtain the absolute maximum of film speed under conditions which permit the film to be exposed to the screen only for a second or so it is better to dispense with panchromatic emulsions. We have tried some of the methods of hypersensitising described in the literature of photography, but any increase in sensitivity so obtained was not commensurate with the extra complication involved.

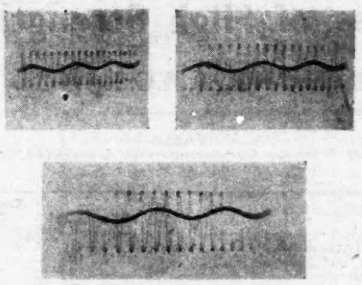


Fig. 3. 6 Mc/s. trace recorded with a 2 in. *f* 1.9 lens, showing reduced intensity towards edges of screen.

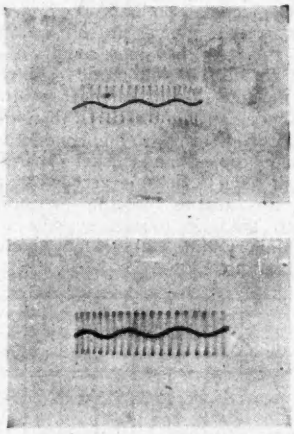


Fig. 4. 6 Mc/s. trace photographed with an *f* 1.9 and *f* 1.0 lens under identical conditions.

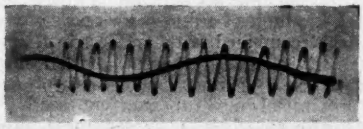


Fig. 5. 12 Mc/s. trace taken with a 2 in. *f* 1.9 lens and intensified. Kodak Ortho X film. Max. writing speed 840 km/s.

For optimum results in development it is best to use the technique specified by the film manufacturers. Generally, this means using a maximum speed and contrast developer such as the Kodak D.19b or the Ilford I.D.33. However, satisfactory results can be obtained with a general M.Q. developer such as the Ilford I.D.2; a dish development time of 4-5 minutes at 65° F., giving maximum density of line without background fog. A staining Pyro developer is sometimes useful because of its good printing properties, but it should not be used if it is suspected that the negative will need intensification as the background will be darkened too much. In this case over-development should be avoided. An important point in connexion with many of the high speed films available to-day is that they should not be kept in store, but should be used as soon as possible. Their speed falls off appreciably with age; in some cases it is necessary to use them within a few weeks of delivery. It is equally important that development after exposure should be carried out with the minimum of delay for the time interval before the sensitivity falls off may be only a matter of hours. A very appreciable increase in negative density can be obtained by intensification. We have found nothing superior to the uranium intensifier for this class of work.

When printing for measurement or for reproduction, it is usually necessary to enlarge the negative, but even if prints of the same size are required it is an advantage to print through a condenser enlarger with projector lamp illumination and no diffuser as greater contrast is thereby obtained. With negatives which have not been coloured by Pyro developer or by intensification, the contrast may be increased still further by using a yellow filter in front of the enlarger lens. Usually, one requires a high contrast printing paper such as Kodak glossy BG.4 or 5. Even greater contrast may be obtained with a gaslight paper such as the Velox VG.5, but its printing speed is something like 60 times as slow as that of the bromide papers. I am told that paper with the contrast of gaslight paper and a printing speed comparable to that of bromide paper is available, but we have not used it so far.

Grid Support Wires of High Strength and Conductivity

By L. B. HUNT, A.R.C.S., M.Sc., Ph.D.*

TABLE
Properties of Mallory 3M Wire by Comparison with Deoxidised Copper and Pure Nickel annealed at 900—950°C.

	Mallory 3M	Deoxidised Copper	Nickel
Tensile strength, tons per sq. inch	40—43	14—16	27—30
Elastic limit, tons per sq. inch	16—18	1—2	4—5
Electrical conductivity, per cent.	80—85	75—90	17—19
Thermal conductivity, cal./cm.²/cm./sec./°C. ...	.74—.78	.70—.80	.14—.16

IN order to avoid or minimise secondary emission it is necessary that grid structures shall be maintained reasonably cool during the operating life of a valve, a temperature of 300° C. usually being taken as a maximum. To keep within this limit a material of high thermal conductivity must be employed for the grid supports, while radiating fins may be fitted at the top in certain cases. Copper has been the obvious material for this purpose, although for more substantial supports some increase in strength has been obtained by the use of nickel wire, at a considerable sacrifice in thermal conductivity.

A further limiting factor is imposed by the manufacturing technique employed, which normally involves the nicking of the support wire, the subsequent swaging of the copper or nickel to enclose the grid wires, and also a stretching operation. Annealed wire must therefore be used for the supports, with the consequence that mechanical properties are extremely low, while still further softening takes place during the high temperature degassing treatment. Damage to the grid may thus easily be caused during handling and assembly, while distortion during service may lead to failure of the valve when the distance between electrodes is small.

A Heat Treatable Alloy

A recent development in connexion with grid supports is the use of an alloy which can be nicked, swaged and stretched in the soft or annealed condition, and can subsequently be given very much greater strength by means of heat treatment during the course of valve manufacture. This material is a ternary alloy of the chromium-copper type known as Mallory 3M, which, after proper heat treatment, combines high mechanical properties with high electrical and thermal conductivity. As supplied to the valve manufacturer, Mallory 3M chromium-copper wire has been given a preliminary annealing treatment to render it soft and ductile, and it is then in a condition suitable for use in automatic grid winding machines. Further heat treatment at moderate temperatures then develops its high strength and conductivity. Unlike copper and nickel, therefore, which tend to become very weak during the heating treatments through which the grid passes, support wires in Mallory 3M will actually increase in strength.

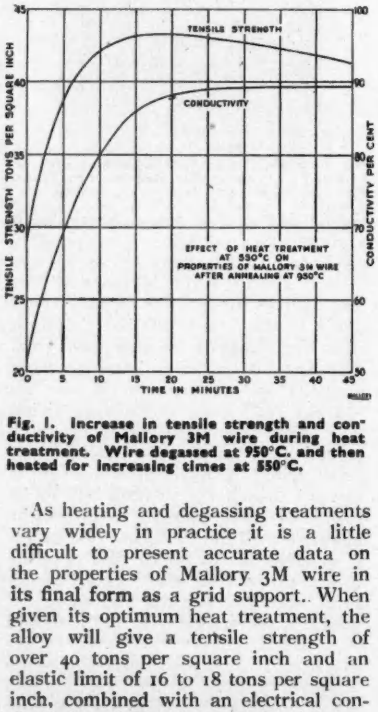


Fig. 1. Increase in tensile strength and conductivity of Mallory 3M wire during heat treatment. Wire degassed at 950°C. and then heated for increasing times at 550°C.

As heating and degassing treatments vary widely in practice it is a little difficult to present accurate data on the properties of Mallory 3M wire in its final form as a grid support. When given its optimum heat treatment, the alloy will give a tensile strength of over 40 tons per square inch and an elastic limit of 16 to 18 tons per square inch, combined with an electrical conductivity of 85 per cent. that of copper, or a thermal conductivity of approximately 0.78 cal./cm.²/cm./sec./°C. For comparison purposes these properties are assembled in the Table alongside those of deoxidised copper and pure nickel, annealed at temperatures corresponding to those normally used in degassing treatments. It will be seen from this table that the mechanical properties, and particularly the elastic limits of Mallory 3M wire, show a great advantage over those of copper, with approximately the same conductivity. (It is not always appreciated that the presence of small amounts of deoxidants in copper causes an appreciable fall in conductivity. In many cases it is found that the electrical conductivity of deoxidised copper does not exceed 75 per cent. of the standard value).

By comparison with nickel wire, Mallory 3M offers a greatly superior conductivity and also a considerable improvement in strength. As supplied, annealed pure nickel wire will have a tensile strength of some 32 tons per square inch with an elastic limit of 8 to 9 tons, but these properties fall to those given in the Table after degassing.

In valve manufacturing practice it may not always be possible to obtain the figures quoted in the table. These properties are actually given by a heat-treatment cycle comprising degassing at 950° C., followed by heating to 550° C. for 15 to 20 minutes, preferably before assembly in the valve. The increase in tensile strength and conductivity with time at this temperature is shown in the accompanying curves. If adherence to this cycle is not practicable, it will still be found that, for the general run of degassing and baking treatments, the properties of Mallory 3M wire will approach the optimum figures sufficiently closely to present a great improvement over either copper or nickel in terms of strength, robustness, and rapid dissipation of heat from the grid. A further advantage is that any more prolonged heating of the supports, provided that this does not exceed about 500° C., will not cause any appreciable softening.

* Mallory Metallurgical Products

DATA SHEETS 59-62

Aerial Characteristics—VI

Thin Cylindrical Aerials

IN the preceding discussion on cylindrical aerials a sinusoidal distribution of current along the aerial has been assumed. This type of current distribution is equivalent to assuming that the cross-sectional dimensions of the aerial are vanishingly small.

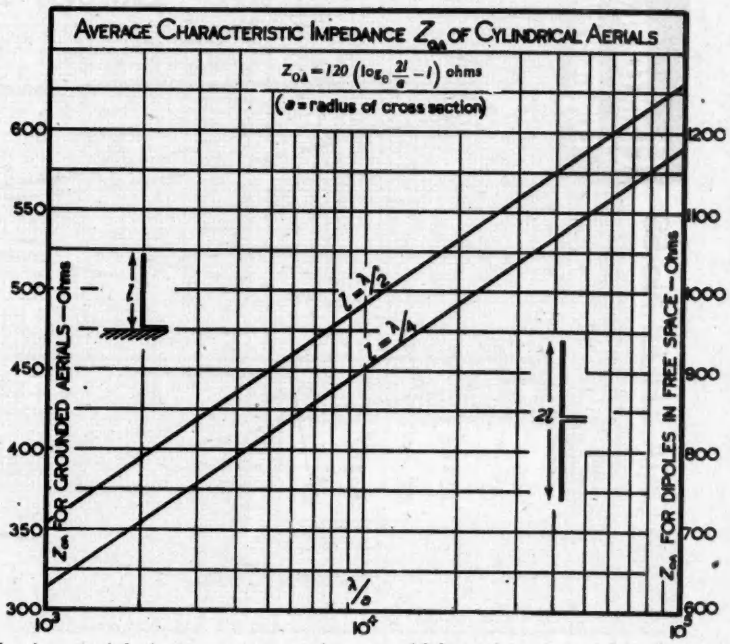
While a reasonably accurate solution for the constants of a cylindrical aerial can be obtained by extending the solution for the conical aerial with the use of the concept of the "Average Characteristic Impedance Z_{0A}" (*see* Part I and (1)), a more rigorous method which also enables the actual current distribution to be obtained was derived by Hallén[2]. R. King and F. G. Blake[3] have used and extended Hallén's work to calculate the input impedance of cylindrical aerials of finite dimensions. The results given in this month's Data Sheets are based on the information provided in the last-mentioned article.

The accompanying Data Sheets give the resistive and reactive components of the input self-impedance of a symmetrical centre driven aerial of half length "l" in free space.

While theoretically the input self-impedance is defined as the impedance across a dimensionless and impedanceless generator connected at the centre of the aerial, in practice it gives the impedance across the small gap between the two ends of the aerial to which the transmission line is connected (*see* Fig. 1). This approximation is, however, only justified provided this separation is a very small fraction of a wavelength.

On Data Sheet No. 59 the resistive and reactive components of the input-self-impedance of a centre-fed aerial in free space are plotted on semi-logarithmic paper against the length expressed in terms of the parameter l/λ. The curves cover a range of cross-sectional dimensions from $\lambda/a = 10^3$ to $\lambda/a = 10^6$ where a is the radius of cross-section. For comparison with the curves in last month's issue on "Conical Aerials" this represents a range of "Average Characteristic Impedance Z_{0A}" of $Z_{0A} = 625$ ohms to $Z_{0A} = 1{,}180$ ohms. For the case of a half-wave dipole in free space and half these magnitudes for a grounded vertical quarter wave aerial over a perfect ground.

In order to provide a larger scale for the curves, the capacitive and inductive aerial input reactance has been plotted on a common ordinate scale the former being designated by a (−) sign and the latter by the (+) sign. Thus, from $l/\lambda = 0$ to $l/\lambda \approx \frac{1}{4}$ the input reactance is capacitive and negative; from $l/\lambda \approx \frac{1}{4}$ to $l/\lambda \approx \frac{1}{2}$ it is inductive and positive, and from $l/\lambda \approx \frac{1}{2}$ to $l/\lambda \approx \frac{3}{4}$ it is again capacitative, etc.



The resistive component of the input impedance represents in all cases the power radiated into space, all loss components having been neglected.

Data Sheet No. 60 gives the lower-resistance and low-reactance regions to an enlarged scale.

As the cross-sectional dimensions of the aerial are increased so the resonant and anti-resonant lengths (lengths for zero input self-reactance) depart further and further from the multiples of $\lambda/4$ required by an aerial having an infinitely small cross-sectional dimension. The curves on Data Sheet No. 61 give the percentage by which the physical length of a dipole must be shortened to operate it under resonant $\frac{1}{2}\lambda$, λ, $\frac{3}{2}\lambda$ and 2λ modes. Thus, for example, a resonant half-wave dipole in free space operated at 5 metres and having a cross-sectional radius of 1 cm., (*i.e.*, $a/\lambda = 2 \times 10^{-3}$) would have its nominal length shortened by 3.7%.

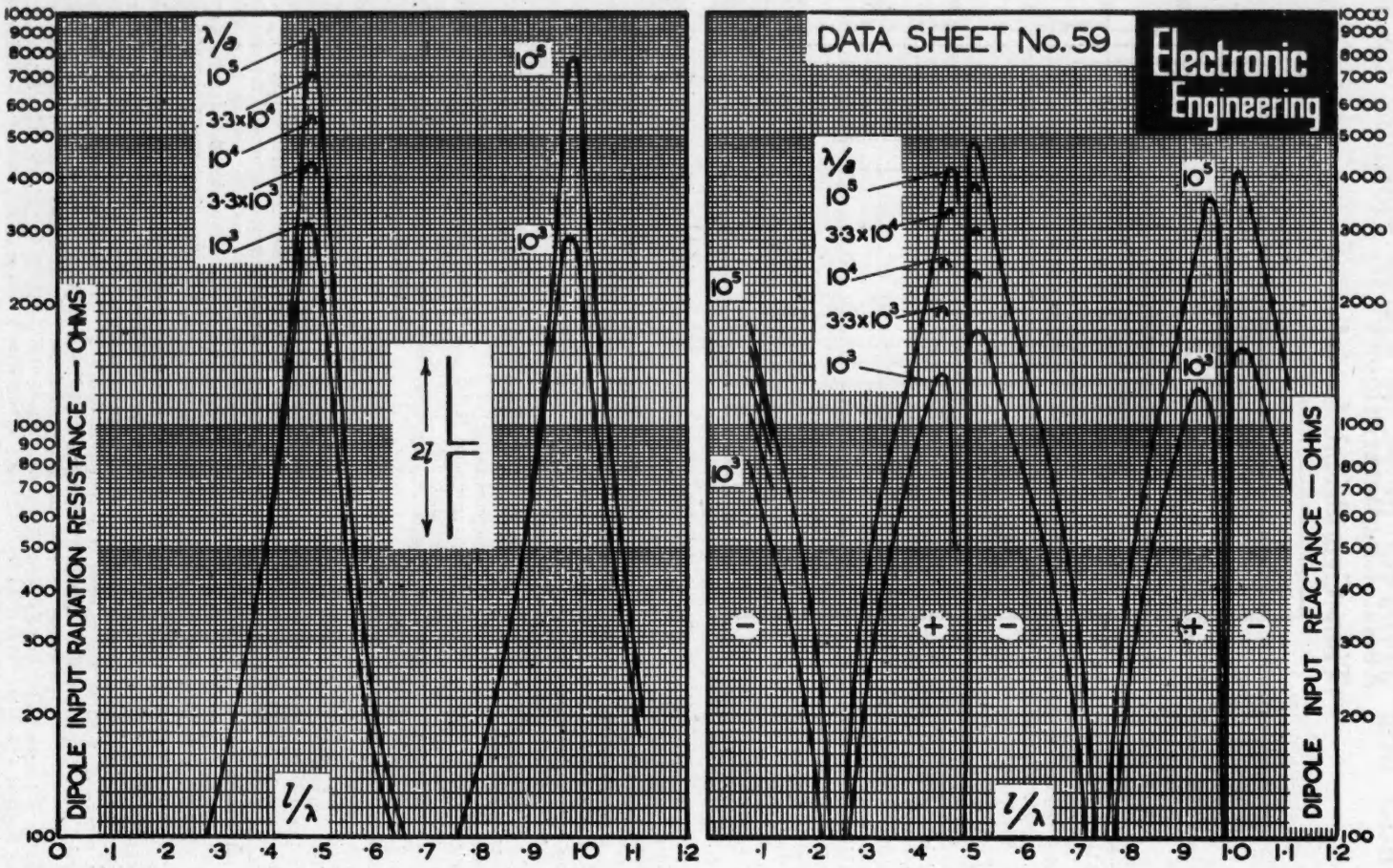
For grounded aerials over perfect ground the same curves are employed, but the $\lambda/2$ or half-wave mode for a dipole becomes the $\lambda/4$ or quarter wave grounded mode; similarly, the curve for the full-wave mode for a dipole is employed for the case of a half-wave grounded aerial, etc.

Data Sheet No. 62 gives the resistive component of the input self impedance of a dipole operating resonantly at $\frac{1}{2}\lambda$, λ, $\frac{3}{2}\lambda$ and 2λ modes (that is with the length shortened in conformity with Data Sheet No. 61). For modes of $\lambda/2$ and $\frac{3}{2}\lambda$ this resistance is the Loop Radiation Resistance R_L of the dipole.

Data Sheets Nos. 61 and 62 can all be used for grounded aerials over perfect ground if the magnitudes of the resistive and reactive components of the input self impedance are halved. The input resistance figures then become the Base Radiation Resistance R_B of the grounded aerial.

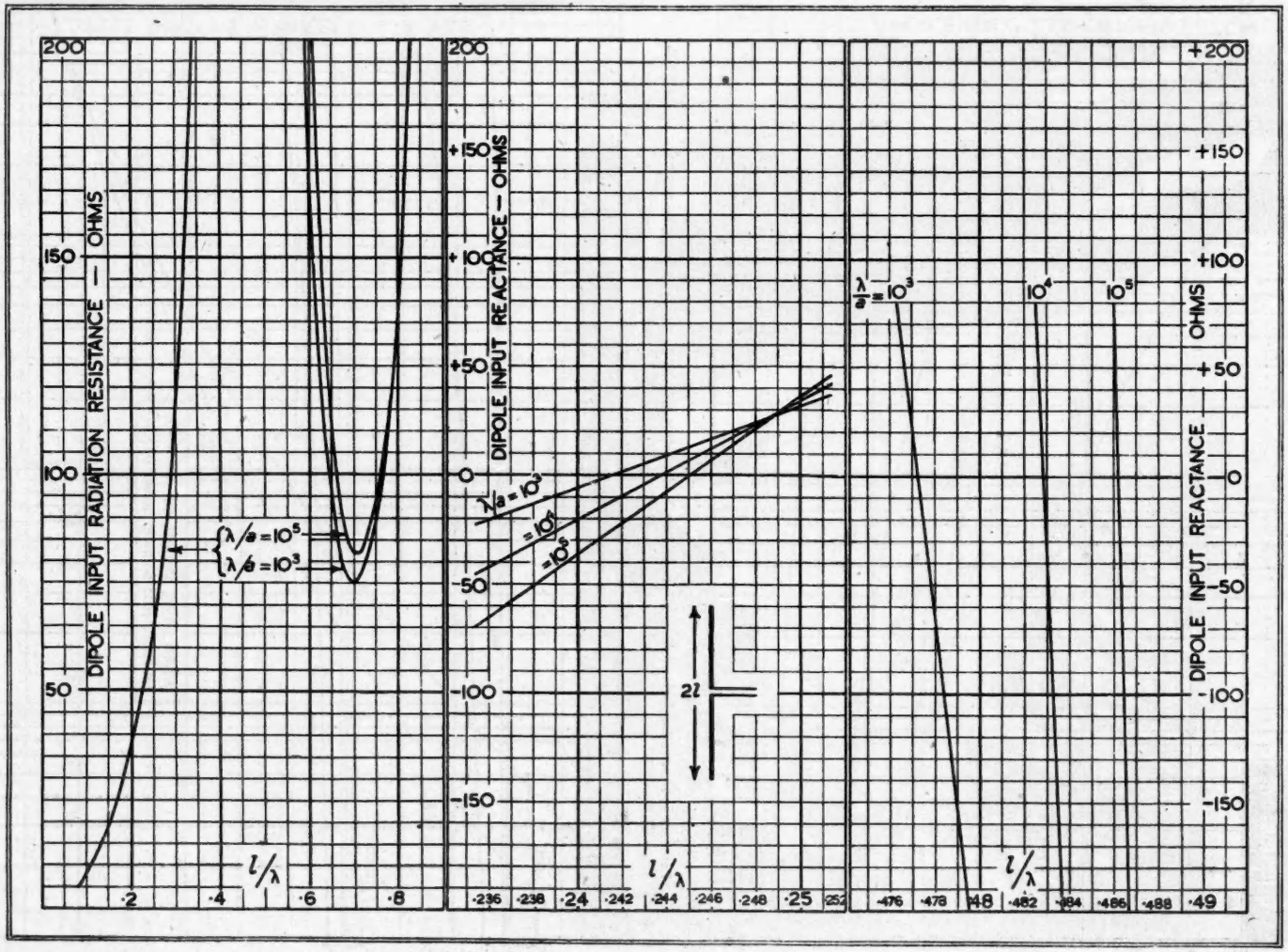
REFERENCES

1 "Theory of Antennas of Arbitrary Size and Shape," S. A. Schelkunoff, *Proc.I.R.E.*, Sept., 1941.
2 "Theoretical Investigation into the Transmitting and Receiving Qualities of Antennas," E. Hallen *Nova Acta* (*Uppsala*), Nov., 1938.
3 "Self Impedance of Symmetrical Antenna," R. King and F. J. Blake, *Proc.I.R.E.*, July, 1942.



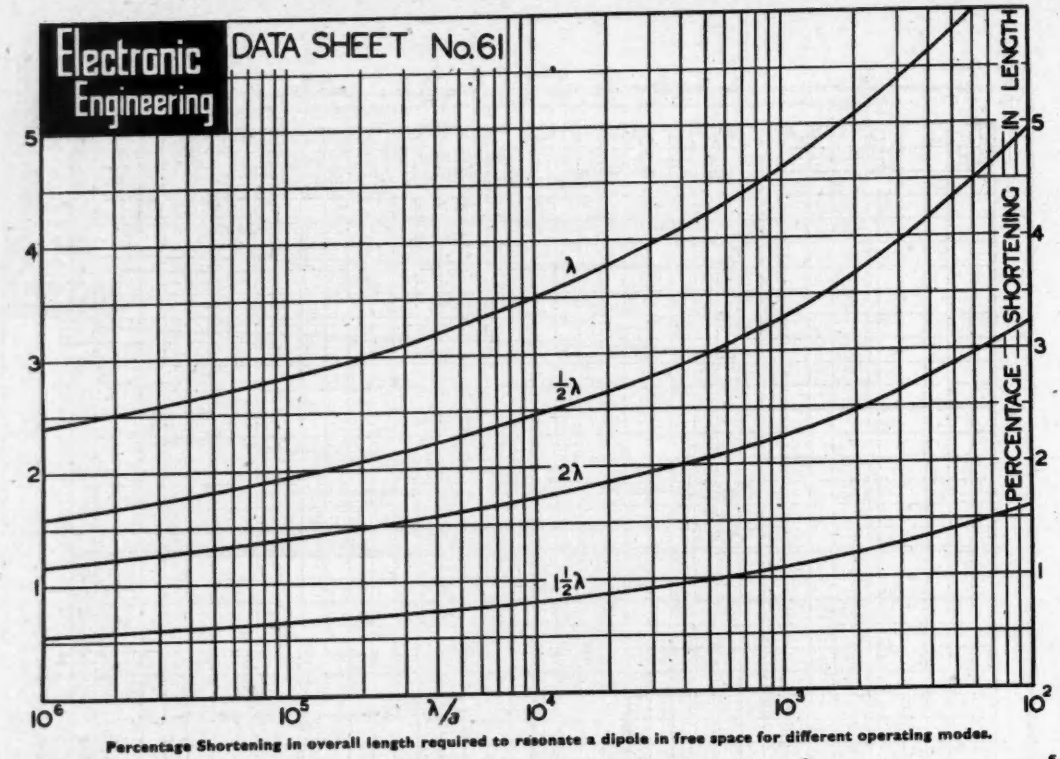
DATA SHEETS 59 and 60. The variation of the resistive and reactive components of the input self-impedance of a cylindrical dipole (in free space) with its length, for finite cross-sectional dimensions. The curves can be applied to grounded aerials over a perfect ground if the values of the resistance and reactance ordinates are halved. The curves below (Data Sheet 60) show the variation in the regions of low resistance and reactance values. In the case of the Input Radiation Resistance, for $l/\lambda < 0.4$ a single mean curve has been drawn. The effect of the cross-section is shown by the following calculated values:

l/λ	$\lambda/a = 10^3$	$\lambda/a = 10^4$	$\lambda/a = 10^5$
0.159	21.4	21.9	22.2
0.25	66.4	68.2	69.2
0.319	150	155	157


DIPOLE INPUT RADIATION RESISTANCE — OHMS
DIPOLE INPUT REACTANCE — OHMS
DIPOLE INPUT REACTANCE — OHMS
λ/a = 10³
λ/a = 10⁵
λ/a = 10⁴
λ/a = 10⁵
2l
l/λ
l/λ
l/λ

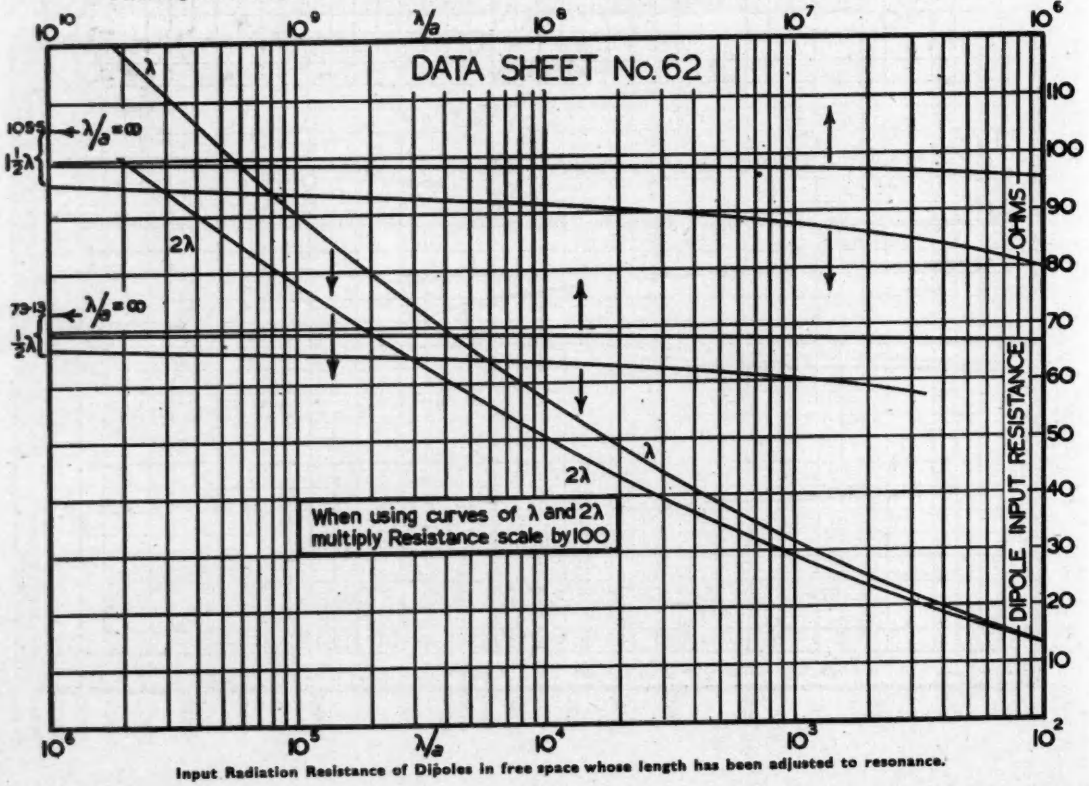
Electronic Engineering

DATA SHEET No. 61

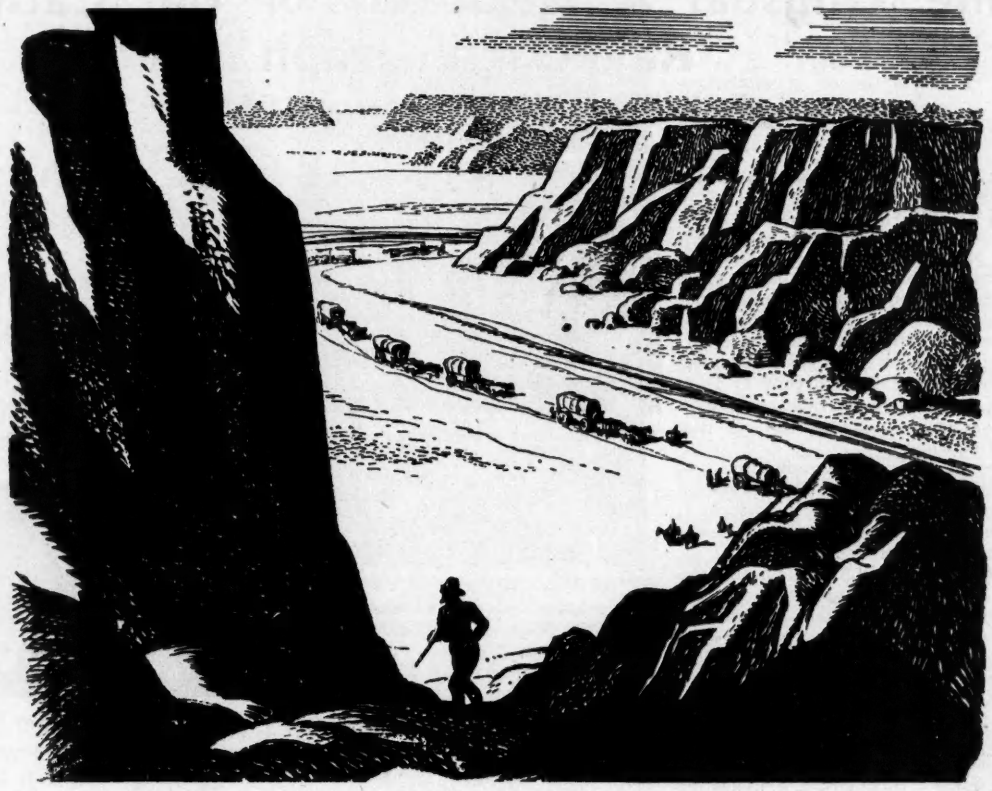


Percentage Shortening in overall length required to resonate a dipole in free space for different operating modes.

DATA SHEET No. 62



Input Radiation Resistance of Dipoles in free space whose length has been adjusted to resonance.



He found a new way

All through the early '40's the covered wagons crawled their painful way across the harsh, pitiless desert. Most of them got through. Not all. Here and there along the scorched trail the little crude crosses told their story. "Dave Slesser is buried here; 14 years old." In 1847 Nathaniel Slocum with his wife, his mother (then aged 61), and four children from one to fifteen years in age, swung his team out of the line, off the bitter waterless track and headed for the hills. His friends argued with him. "You'll lose them all Nat!" "Martha's dying right now" he said. "I'm making for good air and water. If we don't find it we'll die together". Over two months later his wagon rolled with all his family safely into Santa Fé. He had a great tale for the astonished settlers—a new route, winding and high, tough going in places, but new, possible and, above all, with abundant water all the way.

After 1847 there were no fresh graves along the desert trail. It was a route no longer.

• • •

Custom and habit, fear of the unknown; these are the things that keep us to the 'beaten track' even when the track is hard and bad. And that is as true in the processes of industry as ever it was on the Western trails. Simmonds service to Industry is that we try to break away from the 'beaten' track wherever and whenever there is hope or need of a 'better way'.

Simmonds Aerocessories Limited. Great West Road, London · MELBOURNE · MONTREAL · PARIS · NEW YORK · LOS ANGELES

THE SIMMONDS NUT · PINNACLE NUT · SPIRE NUT
SIMMONDS INSTRUMENTS, CONTROLS & ELECTRONIC
PRODUCTS · FRAM OIL & ENGINE CLEANER

SIMMONDS

• New and Better Ways •

C. R. Casson. 1.

Some Unusual Applications of the Cathode Ray Oscillograph

By G. N. PATCHETT, B.Sc. Grad. I.E.E.*

(Continued from p. 196 October Issue)

The Measurement of the Speed of Rotation of a Shaft

THE principle used in the measurement of the speed of rotation of a shaft by means of a cathode-ray tube is to fix to the shaft some device to generate an alternating potential whose frequency is determined by the rotational speed of the shaft. This frequency is then compared with the frequency of a beat-frequency oscillator, the cathode-ray tube being used for the accurate comparison of the two frequencies.

Two methods of obtaining the voltage whose frequency is proportional to the shaft speed will be described, the remainder of the apparatus being the same in both cases.

The best method of comparing the two frequencies is to apply the unknown frequency to the Y deflecting plates of the cathode-ray oscillograph (if necessary through an amplifier) and to apply the output from the beat-frequency oscillator to the X deflecting plates. The frequency of the oscillator is now adjusted until a stationary ellipse is formed on the screen of the cathode-ray oscillograph, indicating that the two frequencies are identical.

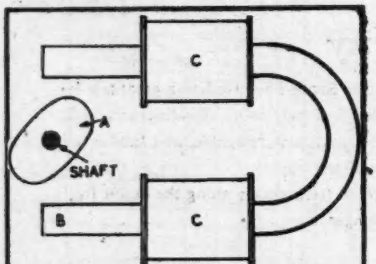


Fig. 5. Arrangement of tachometer for speed indication.

If one revolution of the shaft produces two cycles (as in the apparatus described) the speed of the shaft is given by:—

Speed of shaft (N) = $30F$ r.p.m.

where F is the frequency of the beat-frequency oscillator in c/s.

There are two methods of generating a voltage whose frequency is proportional to the speed of rotation of the shaft:—

(a) This device consists essentially of a very small inductor-type alternator. To the shaft is fitted a small armature of soft iron A, shaped roughly

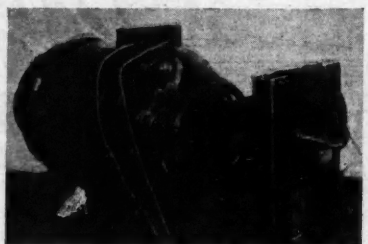


Fig. 6. Photograph of tachometer attached to the shaft of a motor.

as shown in Fig. 5. This revolves between the poles of a permanent magnet B, over the limbs of which fit two coils C. The coils consist of 2,000 or 3,000 turns of thin wire and are connected in series. The movement of the soft iron armature between the poles of the magnet causes a variation of the flux through the coils and so produces an E.M.F. Since the flux reaches a maximum twice per revolution of the shaft, the frequency of the E.M.F. generated by the coils is twice the speed of rotation of the shaft. The waveform generated depends on the shape of the iron armature and is somewhat distorted but causes no difficulty in determining when the frequency is the same as that of the beat-frequency oscillator.

The advantage of this type of frequency generator is that it is cheap and robust. An even simpler arrangement of a straight bar permanent magnet and coil may be used, although the waveform is worse and the voltage smaller. The power required to rotate the armature is much smaller than that required to operate a normal type of tachometer or revolution counter.

A photograph of this type of tachometer is shown in Fig. 6, and the waveform generated is shown in Fig. 7.

(b) This type of frequency generator is more complicated but requires less driving power than (a) and is negligible even with the smallest of motors.

Fig. 7. Waveform generated by the shaped armature of Fig. 5.

The apparatus consists of a light source A (Fig. 8) placed behind a screen B which has a slit in it, as shown in Fig. 8a. A shutter C shaped approximately as shown in the diagram is fitted to the shaft so as to vary the amount of light passing through the slit on to the photo-electric cell D. The output from the photo-electric cell is amplified and fed to the Y plates of the cathode-ray oscillograph. The frequency of the E.M.F. generated by the photo-elec-

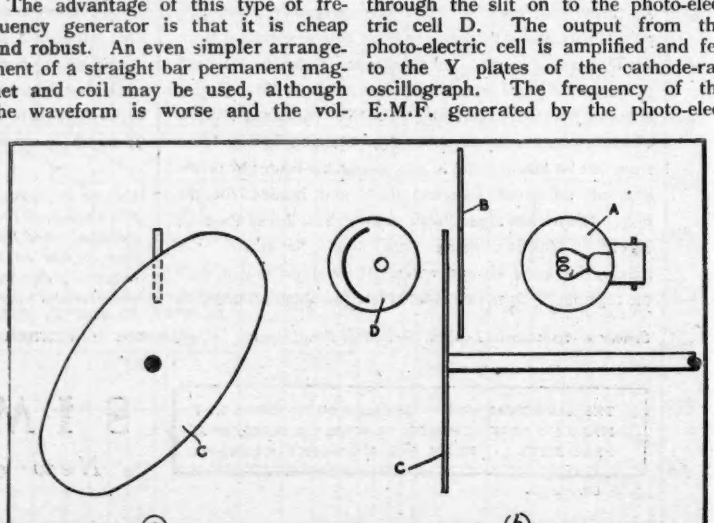


Fig. 8. Another tachometer using a photo-cell and slit.

* Bradford Technical College.

tric cell is twice the speed of rotation of the shaft. The only power required to operate this type of tachometer is that required to overcome air friction of the small shutter C, which is negligible.

The main advantages of the cathode-ray type of tachometer is the very small driving power, unlimited speed range and high accuracy. The small driving power becomes very important with small motors where an ordinary type of tachometer becomes useless. The speed range of the tachometer is determined by the frequency range of the beat-frequency oscillator which can be made to cover any required range, with a much greater accuracy than a mechanical type of tachometer or even speed counter.

The same device may be used to show the slip of an induction motor or the phase shift of the armature of a synchronous motor relative to the rotating field, by connecting the X plates of the cathode-ray oscillograph to the same supply as the machine. In the case of an induction motor with four poles an ellipse will be formed which turns itself "inside out" at the slip frequency of the machine.

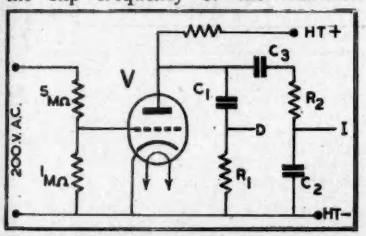


Fig. 9. Circuit for showing integration and differentiation of a square waveform.

With a four-pole synchronous machine the movement of the armature relative to the field (caused by "hunting" or change of load) will cause a change in shape of the ellipse, the actual angular movement of the armature being calculable from the shape of the two ellipses formed. With a machine having a different number of poles an armature or shutter with a number of "poles" equal to half the number of poles on the machine, would be more suitable and give the same result as the four-pole case.

The Use of the Cathode Ray Oscillograph for Integration and Differentiation

The circuit of the apparatus for the integration and differentiation of a square waveform is shown in Fig. 9. The circuit may be used with modifications for the differentiation and integration of any waveform either recurrent or of a transient nature, the square waveform being used only as an example.

The square waveform is produced

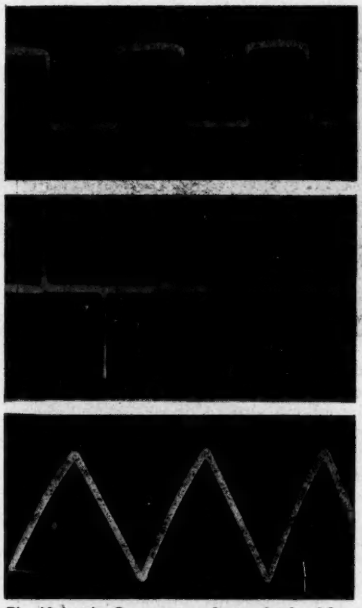


Fig. 10 (top). Square waveform obtained from the circuit of Fig. 9.
Fig. 11 (centre). The same wave differentiated.
Fig. 12 (bottom). Result of integrating the square wave.

by the valve V, which is fed with a large 50 c/s. input so that it is driven far beyond cut-off and also into grid current. Due to the high resistance in the grid circuit the flow of grid current limits the actual positive voltage to the valve, and so both positive and negative halves of the input waveform are limited, thus producing an approximately square waveform as shown in the photograph reproduced in Fig. 10.

Differentiation

The output of the valve V is fed into a differentiating circuit consisting of a resistance R_1 and a condenser C_1. Resistance R_1 has a value of 1,000 ohms and condenser C_1 a capacity of 0.004 μ F, giving a reactance of the condenser at 50 c/s., of approximately 800,000 ohms.

Since the reactance of the condenser C_1 is much greater than the resistance R_1, the current I through this circuit is proportional to dV_a/dt where V_a is the A.C. anode voltage of valve V. The voltage across the resistance R_1 is proportional to the current I. Therefore, the voltage across the resistance R_1 is proportional to dV_a/dt. The result of differentiation of the square wave is shown in Fig. 11.

Integration

For integration, the output of the valve V is fed into the circuit consisting of resistance R_2 and condenser C_2 (the condenser C_3 acts as a D.C. blocking condenser only).

In this case the reactance of the condenser C_2 must be much less than the resistance R_2. The values used were $R_2=3$ megohms and $C_1=0.1$ μF (giving a reactance at 50 c/s of approximately 30,000 ohms).

$C_2 \propto \int I dt$. Therefore, the voltage across $C_2 \propto \int V_a$.

The current through the resistance R_2 and condenser C_2 is proportional to the voltage V_a. The voltage across The result of integrating the square wave is shown in Fig. 12. The voltage output of either of these circuits is much smaller than the anode voltage change of valve V, and it is necessary to amplify the output in order to feed the oscillograph.

These circuits can be applied equally well to any frequency or waveform and, as already stated, to transient waveforms by choosing suitable values for the resistances and condensers. One example of the use of the circuit for a transient is the measurement of the acceleration of a motor by coupling to it a permanent magnet (or constant excitation) generator. The

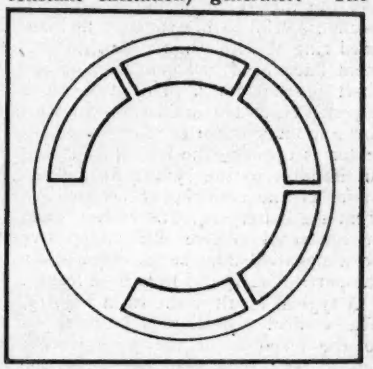


Fig. 13. Filter disk for measurement of colour response.

output of the generator is proportional to the speed, and therefore if this voltage is fed to a differentiating circuit the output will be proportional to the acceleration of the machine.

Measurement of the Colour Response of a Photo-Electric Cell

The principle of this application is to rotate in front of the photo-electric cell a colour filter corresponding to the spectrum, and to synchronise the time base of the oscillograph with the rotation of the filter.

The filter was built up as shown in Fig. 13. This was constructed from cardboard with the colour spectrum spread out between the five sectors. The arrangement of the apparatus is shown in Fig. 14. The filter is rotated by a small motor M in front of a mask M′ which allows a

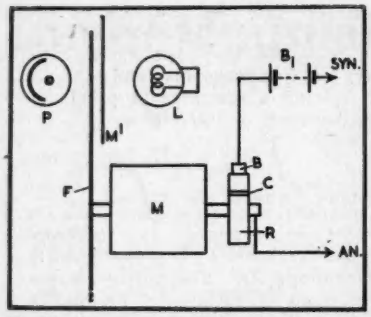
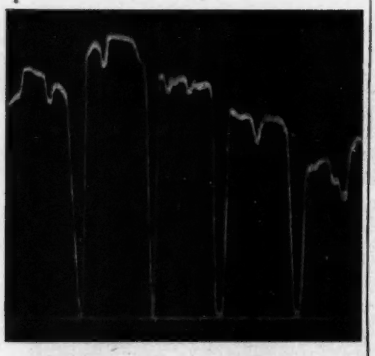


Fig. 14. Arrangement of apparatus for determining colour response, and Fig. 15. Curve of response of photo-cell obtained.



small slit of light to pass from the lamp L to the photoelectric cell P, through the filter.

The arms of the filter disk between the sectors cut off the light as they pass the slit in the mask M' and are used for the calibration of the X axis of the oscillograph. The blank sector also prevents any confusion as to the correct phase between the time base and the rotation of the filter disk.

The synchronising between the motor and the time base of the cathode-ray oscillograph is achieved by the insulated ring R with a narrow metal segment fixed in it and connected to the shaft of the motor. The segment is adjusted so that it makes contact with the stationary brush B when the blank sector is opposite the slit, thus giving an impulse to the synchronising terminal of the cathode-ray oscillograph from the battery B_1. The battery must be connected to give either a positive or a negative impulse as required by the particular type of time base in use.

A typical result is shown in Fig. 15. The vertical deflection is proportional to the response of the photo-electric cell at any particular colour of the light. The positions of the five arms of the filter disk are visible where the Y deflection drops to zero. The speed of the disk should not be too fast or errors may be introduced due to the frequency response of the cell. If quantitative results are required as distinct from comparative results, a correction must be applied for the colour distribution of the lamp, unless this has been allowed for in the construction of the filter disk.

The apparatus may also be used in the reverse way, *i.e.*, if the colour response of the cell is known, the colour response of the light may be determined.

The Measurement of the Wavelength of Sound Waves

The principle of the measurement of the wavelength of sound waves using a cathode-ray oscillograph, is to measure the phase difference between the sound at a loud-speaker and a microphone situated near it, and then to displace one relative to the other until the phase difference is again the same. The displacement then gives the wavelength of the sound.

The loud-speaker is fed from an audio-frequency oscillator of suitable frequency, and the voltage across the loud-speaker is connected to one beam of a double-beam cathode-ray oscillograph. The voltage developed by a suitable microphone (a carbon type being quite suitable) situated in front of the loud-speaker is fed to the other beam of the oscillograph. The time base of the oscillograph is adjusted to give a suitable number of cycles on the screen and synchronised with the voltage across the loud-speaker. A movement of the microphone relative to the loud-speaker causes the waveform of the microphone voltage to move relative to the speaker voltage waveform, due to the change of phase of the sound at the microphone. To obtain the wavelength of the sound wave the microphone is adjusted so that the two waveforms are in phase. The position of the microphone is noted. The microphone is now moved either nearer or further from the loud-speaker until the *first* position is found where the waveforms are again in phase. The movement of the microphone is a measure of the wavelength of the sound, at the particular frequency being used.

If a double-beam oscillograph is not available the phase change may be measured by a single-beam tube by feeding the loud-speaker voltage to the X plates and the microphone voltage to the Y plates, in the well-known way.

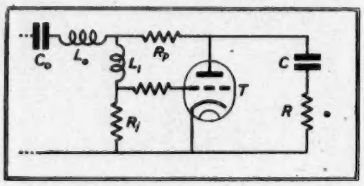
The method gives accurate results since it does not depend on the quality of the loud-speaker or microphone, since these are the same in both cases. The only precaution necessary is to avoid reflections from nearby objects which cause the formation of stationary waves.

H.F. Oscillations from Thyratrons

In the October, 1943, issue of the *Bell Laboratories Record*, L. G. KERSTA describes how thyratrons can be made to produce much higher frequencies that had previously been thought possible if they were operated in a new circuit which accelerates the ionisation and deionisation of the gas.

The harmonics generated in the circuit provide standard frequencies as high as 25 Mc/s. for calibration of oscillators, testing pulses, high speed triggering, etc.

In the circuit, which is shown in the figure, the anode and grid are both supplied from the same a.c. source. The negative half-cycle, particularly when applied to the grid, sweep the gas ions quickly from the tube and increase the rate of deionisation.

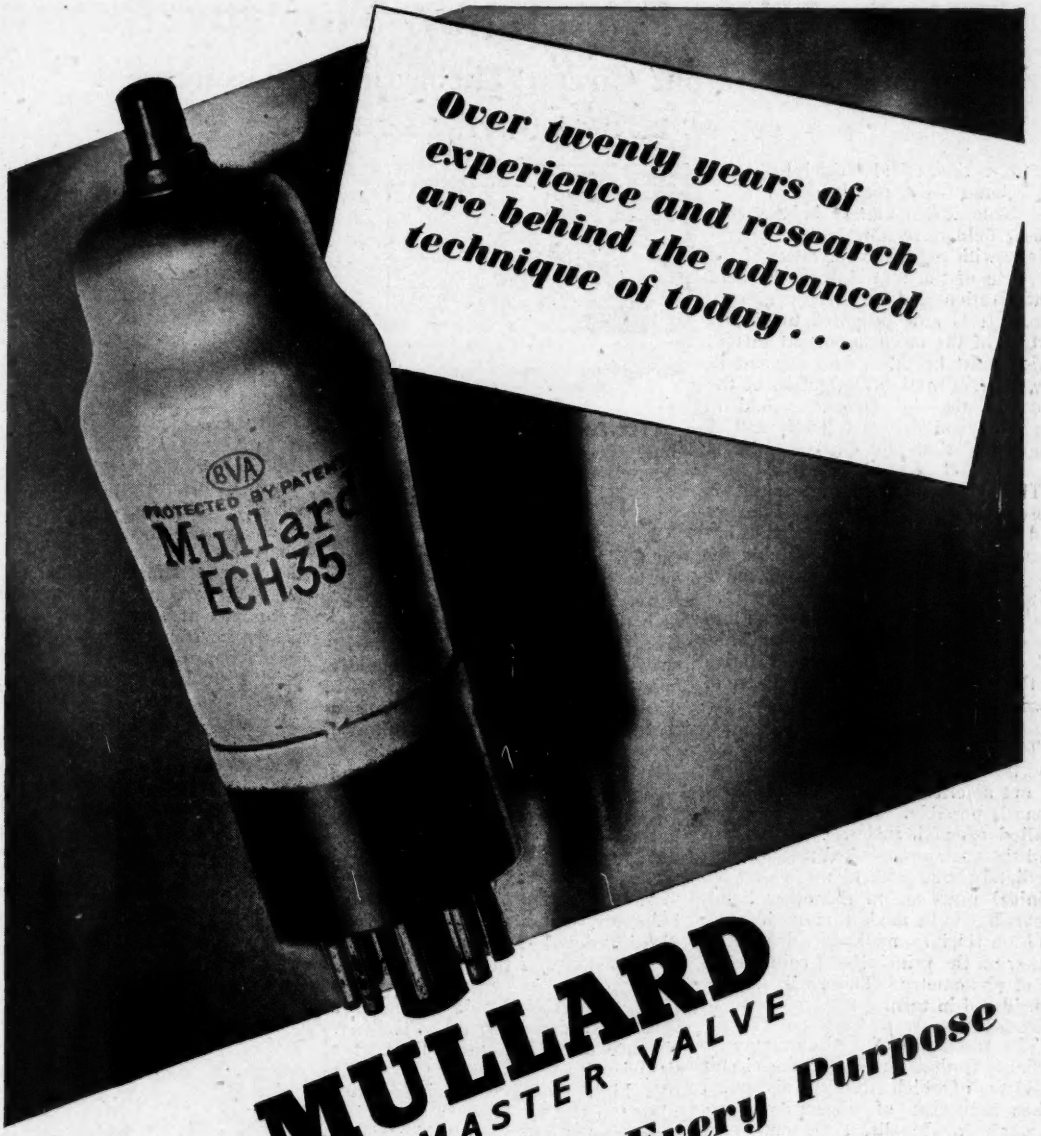


An oscillatory voltage of several kilocycles per sec. is applied to the circuit $C_0L_0L_1R_1$. The drop across the coil L_1 charges the condenser C through the resistances R_p and R.

The firing time of the thyratron T is adjusted to occur near the peak of the voltage wave impressed on the output circuit CR. This time is largely determined by the relative phases of the grid and anode potentials. When the anode is positive and the grid exceeds the striking potential condenser C discharges through the thyratron and the resistance R, producing a pulse of current which increases very rapidly to a maximum and then falls off at a rate determined by the CR product. This pulse generates the high frequency harmonics.

For values of $1/CR$ from 20 to 600 Mc., the pulses lasted from 0.5 to 0.05 microseconds.

It is pointed out that the grid plays a major part in deionising the tube, and the results show that the deionisation time for a gas-filled tube is not a definite quantity and the striking characteristics are significant only under specified conditions and at low frequencies. At higher frequencies the striking characteristic depends on the waveform of the grid voltage and the discharge constants of the grid circuit.


Over twenty years of experience and research are behind the advanced technique of today . . .
BVA
PROTECTED BY PATENTS
Mullard
ECH35

MULLARD

THE MASTER VALVE

A Valve for Every Purpose

DOMESTIC · COMMERCIAL · INDUSTRIAL · SCIENTIFIC · MEDICAL · EXPERIMENTAL

THE MULLARD WIRELESS SERVICE CO. LTD., CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2. (75)

High Frequency Therapy

Part VI.—Output Circuit Theory and Measurement

by W. D. OLIPHANT, B.Sc., F.Inst.P.*

THE theoretical principles associated with the insertion of a biological material in the condenser field have now been discussed chiefly with regard to the effect of the presence of the material on the field configuration and on energy absorption. It is now proposed to discuss certain of the more important factors which must be taken into account in any experimental investigation of the effects of the high frequency field on the biological material itself, and at the same time to outline suitable experimental methods.

The question of power output is closely associated with that of dosage and it is a matter of extreme importance that means be available for its measurement. By the effective power output of a machine is meant the total power which is delivered into the output load (the patient), and this, taken in conjunction with the duration of the exposure, provides a measure of dosage.

Effective Power Output Measurement

There are several possible methods and the choice will depend on whether or not a series of protracted observations is possible. In the case of controlled research this will be the case and the various electrical methods immediately suggest themselves. In clinical practice, on the other hand, resort has to be made to more indirect and artificial methods depending either on the principles of calorimetry or of photometry. These will now be considered in turn.

Electrical Methods

The resistance of a circuit may be defined as that quality of the circuit in virtue of which energy is dissipated when a current of electricity flows through it. In direct current work Ohm's law provides a simple practical definition, while in alternating current work at low and medium frequencies a practical definition is derived from Joule's law. At very high frequencies, however, in addition to the electrical energy dissipated in the form of heat, account must be taken of the energy which is radiated into space as a radio wave. In general the *effective* resistance of a circuit (or part thereof) may be defined as the ratio of the rate of energy dissipation in the circuit (or part thereof), W, to the square of the effective value of the current (I) flowing through it, thus

$$R_e = \frac{W}{I^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

The rate at which the electrical energy is dissipated is termed the power loss and the measurement of power will depend on a measurement of both effective resistance and effective current. The effective resistance is essentially a positive quantity being associated with an outflow of dissipated energy; it would be a negative quantity if there was an inflow of energy of a non-electrical nature.

1. *Effective Resistance Measurement.*

The effective resistance of the output circuit of a therapy machine is the sum of the effective resistances of the various circuit elements; that is to say the patient, electrodes, wiring, inductors, capacitors and current indicating device, and, as it is the effective resistance of the patient which is necessary, a separate investigation must be carried out in the majority of cases to determine the effective resistance of the whole of the rest of the circuit. The effective resistance of a high frequency circuit is a complex function of frequency and it is thus necessary to conduct the measurements at the operating frequency or, at any rate, within a narrow band about that frequency. Suitable methods of measurement will now be considered.

The simplest method is that of direct substitution and as it is only applicable to part of a circuit, it is arranged to substitute a suitable resistance in place of the biological material. In a control experiment it is possible to insert the material with its associated electrodes in an auxiliary circuit shown in Fig. 1.

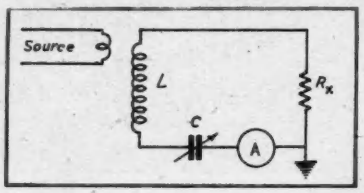


Fig. 1. Measurement of effective resistance by substitution of a standard.

Resonance is obtained by means of the variable condenser C, and the current is then read on a suitable ammeter A. A standard h.f. resistor is now substituted for the unknown resistance R_x to give the same resonant current. If the substitution has so changed the inductance or capacitance of the circuit, then retuning by means of C will introduce no serious error for an undamped induced e.m.f. provided that the readjustment of C has been associated with a known change in its effective resistance. Then, provided the induced e.m.f. from the source is unchanged by the substitution, R_x is equal to the standard. This presupposed that the standard resistance is of exactly the same value as the unknown, and, apart from any question of coincidence, it calls for a continuously variable standard h.f. resistor. As such a component is extremely difficult to design for frequencies of a high order, resort has to be made to a selection of fixed values. In this case it is necessary to extend the theory to cope with unequal deflections.

Let R_x give a current I_x. Substitute for R_x a known and similar resistance R_s and let this give a current I_s. Finally, add another resistance R_s' and let the resulting current be I_s'.

Then if R be the effective resistance of the rest of the circuit, and assuming a constant undamped induced e.m.f. from the source it can be shown that

$$R_x = R_s + R_s' \cdot \frac{\left(\frac{I_s}{I_x} - 1\right)}{\left(\frac{I_s}{I_s'} - 1\right)} \quad \ldots\ldots\ldots \quad (2)$$

This method is both convenient and rapid, but it cannot be relied upon to give a high degree of accuracy unless rigorous precautions are taken. For example, when using a sensitive ammeter in conjunction with loose source coupling, it is found that the accuracy is considerably impaired by the induction of secondary e.m.f.s in the various circuit elements. These e.m.f.s are dependent on the general layout and configuration of the circuit, and the process of substitution itself may seriously alter the effective spurious e.m.f. with consequent effect on the measured current. This difficulty is closely associated

* University of St. Andrews.

ADVERTISEMENT OF THE TELEGRAPH CONDENSER CO., LTD.
GA

with the earthing of the entire circuit including that of the source itself. It can only be said here that the fruits of bitter experience will eventually render the investigator an expert at high frequency measurement work; to indulge in a dissertation on these methods would require a series of articles all to itself!

Another simple method which determines the *entire* circuit resistance is known as the *resistance variation method*. To apply this method to the problem in hand, it would be necessary to determine the total circuit resistance with the biological material in position, and then to repeat the operation with it removed—a direct subtraction giving the effective resistance of the material. As the insertion of the biological material will bring about a radical change in the effective circuit capacitance, it is necessary to know the effective resistance of the condenser as a function of capacitance.

The resistance variation method is briefly as follows. The value of the current at resonance (I) in a simple auxiliary circuit as in Fig. 1 is noted. A known resistance R_1 is then inserted in series in the circuit and a new resonance current I_1 is observed. If R be the effective resistance of the entire original circuit, then it can easily be shown that

$$R = \frac{R_1}{(I/I_1 - 1)} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

The experiment is generally repeated with a number of known added resistances and the mean value of R taken. As in the substitution method, precautions are the keys to accuracy.

The two methods just described depend for their operation on the possession of a set of standard h.f. resistors, and, with ultra-high frequency operation well in sight, their design and reliability, is an open question. The accuracy of the methods is dependent on an exact knowledge of the value of the resistance inserted and this calls for a standardisation experiment. At ultra-high frequencies, where the methods available are open to much criticism, it is necessary to fall back on a calculated value. Such a value can be very reliable but stray effects, which are present when the standards are in use, produce a great unknown quantity. In many respects, therefore, the third method about to be described effectively overcomes these difficulties.

The method avoids the necessity of having to alter the measurement circuit in any way, and it also has the great additional advantage that all the necessary adjustments and observations can be made on the actual patient circuit of the therapy machine itself, or at any rate, after certain minor modifications have, in certain cases, been made. It is known as the *reactance variation method* and is based on the theory associated with the resonance curve of the circuit. The patient circuit is tuned to resonance by a variable condenser and a calibration of this component is necessary. The current in the circuit is measured by a suitable ammeter which must also be calibrated.

If E be the constant e.m.f. of pulsatance* ω induced in the circuit, and if I_r be the resonance current, then $I_r R = \frac{E}{R}$ and the circuit reactance, X, is zero.

The reactance is now varied from zero to some value X_1 with a corresponding current I_1 given by

$$I_1 = \frac{E}{\sqrt{R^2 + X_1^2}}$$

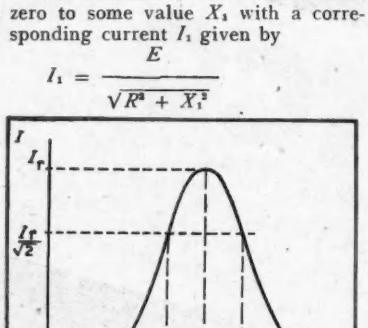


Fig. 2. Determining R by reactance variation.

It is thus evident that

$$R = X_1 \sqrt{\frac{I_1^2}{I_r^2 - I_1^2}} \quad \ldots\ldots\ldots\ldots (4)$$

If X_1 is obtained by reducing the resonance capacitance C_r to some value C_1, then

$$X_1 = \frac{1}{\omega}\left\{\frac{C_r - C_1}{C_r\, C_1}\right\} \quad \ldots\ldots\ldots\ldots (5)$$

The current value I_1 could also have been obtained by *increasing* the capacitance from C_r to C_2, in which case

$$X_1 = \frac{1}{\omega}\left\{\frac{C_2 - C_r}{C_2 \,.\, C_r}\right\} \quad \ldots\ldots\ldots\ldots (6)$$

If it is so desired, C_r may be eliminated in which case the final result is given by

$$R = \frac{1}{2\omega} \,.\, \frac{C_2 - C_1}{C_1 \,.\, C_2} \sqrt{\frac{I_1^2}{I_r^2 - I_1^2}} \quad (7)$$

Finally, if I_1 be made equal to $\frac{I_r}{\sqrt{2}}$ the term under the radical becomes unity and so the final equation becomes

$$R = \frac{1}{2\omega}\left\{\frac{C_2 - C_1}{C_1\, C_2}\right\} \quad \ldots\ldots\ldots\ldots (8)$$

It is thus only necessary to note the capacitances C_1 and C_2 which give a circuit current of $I_r/\sqrt{2}$, and then apply equation (8). Fig. 2 shows this state of affairs graphically.

There are many other possible methods of determining the effective resistance of either an entire circuit or of a part thereof, but they all involve more complicated adjustments and their treatment falls outside the scope of this series.

2. *Effective Current Measurement.*

Means for measuring the effective (or r.m.s.) value of a high frequency current are contained in such instruments as the thermocouple ammeter and the hot-wire ammeter, together with the possible use of an air-cored current transformer.

Thermo-couple instruments are invariably the most reliable, though they require to be calibrated within the working range of frequency. A number of elementary precautions have to be taken in their use and these include insertion of the current element into the measurement circuit adjacent to the earth point, and also the inclusion of suitable chokes and by-pass condensers in the galvanometer circuit. The couple may be incorporated along with the current element within a small evacuated glass bulb, or the current element may comprise a number of linear conductors arranged in parallel in squirrel cage fashion, the couple being attached to one of the elements.

Hot wire ammeters depend for their action on the linear thermal expansion of the current element and they also require to be calibrated to take account of skin effect in the current element.

Calorimetric Methods

These methods depend on the measurement of the quantity of heat generated in substances of known thermal properties when placed in the condenser field. They provide a convenient and accurate means for measuring the degree of loading in clinical practice.

The most suitable type of calorimeter vessel is the well-known Dewar flask. This is a double-walled glass vessel with the space between walls evacuated, but it is essential that the boundary walls of this evacuated space be not silvered. Furthermore, the glass should be of such a type that high frequency losses are negli-

* Pulsatance $= 2\pi f$

gible. The flask, containing a suitable quantity of distilled water, is placed in the condenser field. Common salt is then added until the degree of damping (as indicated by the machine ammeter) is the same as that of the patient whose loading effect it is desired to determine. The solution is efficiently stirred and the rise in temperature is noted over short time intervals. This gives an accurate measure of the rate of rise of temperature — θ/t °C./sec. The water equivalent of the calorimeter and its contents is then determined (W gm.) and so the power dissipated is given by

$$4.2\ W. \frac{\theta}{t} \text{ watts.}$$

Photometric Methods

These methods have the practical advantage that they can be made direct reading, but they only provide a very rough estimate of the actual loading as the electrodes have to be applied to the measuring apparatus. A simple arrangement is shown in Fig. 3.

An ordinary filament lamp of suitable maximum wattage is calibrated in conjunction with a portable photometer set at some fixed point with respect to the lamp. The power dissipated in the lamp can be readily measured and the degree of illumination at the photometer noted. It is then only necessary to read the photometer which could, if desired, be scaled to read direct in watts. To enable the generator to be connected to the lamp, the lamp is provided with a pair of planar electrodes, E, as shown, and the machine electrodes are then suitably spaced to present as near as possible the same degree of loading as was produced by the patient.

Experimental Investigations in the Condenser Field

Experiments on Micro-organisms

Many experimenters have published results in this field of investigation, and some have gone so far as to stress evidence in favour of specific action. In these experiments bacteria and other micro-organisms have been exposed to the condenser field and the conditions bringing about lethal action have been noted. One investigator went so far as to place on record the fact that certain bacteria succumbed to a lower temperature in the condenser field than in the standard controlled hot-water bath test. Positive evidence has not so far been established in favour of specific action and it is instructive to consider the many variables which are present in an investigation of this nature.

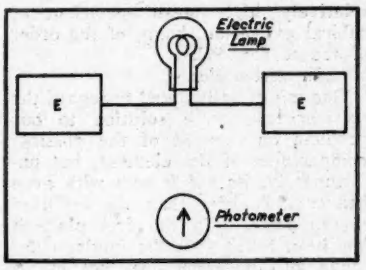


Fig. 3. Measurement of power by photometric method.

Having chosen a certain micro-organism as our subject for observation, it is necessary to conduct a preliminary study of its health; that is to say to investigate its virulence, age and past metabolic history. This is particularly necessary when carrying out a number of experiments on the same type. The organism must be maintained *in vitro* in a suitable medium, the biochemical and biophysical properties of which must be known; and preliminary tests should be carried out to ascertain whether or not the medium itself does in fact undergo a change in the condenser field; a change which may deprive the organism of its means of subsistence. The culture medium in its turn must be contained in a suitably shaped vessel and the resultant field configuration must be taken into account.

These difficulties are small by comparison with the crucial test, namely, that of measuring the body temperature of the organism itself. For the moment we will assume that the temperature may be accurately measured within the substance exposed to the condenser field and it would seem, therefore, that the temperature of the culture medium would provide us with the necessary data. This, however, assumes that the body temperature of the organism is the same as that of its super-incumbent medium, an assumption which has been responsible for present controversy in the discussion of experimental results. We must regard the organism as a material particle in suspension and expect field concentration about it. The organism will thus be raised to a much higher temperature than that recorded for the culture medium as a whole. The magnitude of this localised temperature is dependent on the size of the organism and on both its own thermal properties and on those of the medium. It is also dependent on the electric field intensity and on the duration of the exposure. There is as yet no reliable precision method of measuring the intensity of the generated electric field at any chosen point in it.

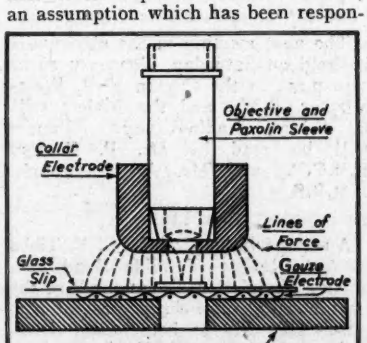


Fig. 4. Holzer and Weissenberg's microscope for observing the effect of the condenser field on an organism.

Many experimenters have employed insects and animals, and it has been found that, with a given source of energy, the effects are proportionately higher in micro-organisms than in the more complex organisms—the insects and animals. The effects are dependent on the biophysical organisation within the organism, that is to say upon the circulatory system and its ability to dissipate heat which has been generated locally.

In order to observe directly the morphological and histological effects of the condenser field on organisms and tissues, Holzer and Weissenberg (in *Grundriss der Kurzwellentherapie*) have described a specially modified microscope, the essential details of which are shown in Fig. 4.

A simple condenser, comprising a brass collar and a piece of fine metallic gauze for electrodes, was incorporated in a standard model of microscope. The objective lens was mounted inside a piece of paxolin tubing, and to the outside of this was attached the brass collar, thus forming one insulated electrode. The collar was suitably bored to provide an aperture for the objective lens and the lower edge of the collar was well rounded (as shown in the diagram) to give a more uniform field distribution. The gauze electrode was supported on the slide carrier on a sheet of paxolin, while the glass slip with the object under observation was placed on the gauze. The electrodes were connected to a suitable output circuit which contained a means for compensating for changes in electrode capacitance brought about during the focusing of the microscope. This compensating adjustment is essential in all cases where resonance in the output circuit prevails. The gauze does not affect the optical field of the instrument as it is optically well below the object. The lines of electric force are shown dotted in the diagram.

Temperature Measurements

In the vast majority of thermal experiments, the accurate measurement or recording of temperature is undoubtedly the simplest operation and the investigator has at his disposal a great variety of instruments which depend for their action on such physical phenomena as the thermal expansion of a fluid, the thermoelectric effect, or the change in the electrical constants of various devices. The effect of the presence of the measuring instrument can, in general, be easily accounted for, but, when we come to consider the measurement of the temperature distribution in a dielectric medium which is being subjected to a high frequency electric field, we are confronted with many grave difficulties.

1. *Fluid Thermometers.*

A fluid thermometer depends for its action on the cubical expansion of an index substance which may be either a liquid or a gas—a mercury thermometer is a good example of the liquid variety though the mercury happens to be a metal. To use such an instrument it would be necessary to introduce the bulb into the electric field, and, if the index fluid was dipolar, a serious error would arise due to localised heating within the index fluid itself. To overcome this inherent defect, a number of experimenters have found benzol to be a suitable thermometric substance both on account of its non-dipolar properties and of its relatively high mean coefficient of cubical expansion, being of the order of 120×10^{-5} °C.

2. *Thermocouples.*

One might be tempted to regard the thermocouple as a solution to our problem on account of the possible compactness of the element, but unfortunately, its use is met with even graver difficulties than the ordinary thermometer. In the first place it has been found that the fundamental mode of operation does not in all cases apply when the couple is exposed to the condenser field, and so any prior calibration is rendered invalid. Again, currents are induced in the couple circuit which bring about localised heating in the junction itself. In addition to the above defects brought about by the effect of the field on the couple, the couple also exerts an effect on the field. The element is essentially a metallic object which has been inserted into the body of the dielectric, and so the field becomes concentrated with consequent local rise in temperature. This effect has most disastrous results when the dielectric body is small.

3. *Thermoscopes.*

There are a great many substances which change either their state or their colour at some definite temperature and they are thus said to be thermoscopic. Unfortunately, the number of such materials is very limited and so a useful range of temperatures cannot be realised. It is worth noting, however, that a large number of demonstration experiments can be carried out using blocks of agar which have been suitably treated with a thermoscopic material. For example, the profile of a face may be carved out and the finished block mounted between a pair of electrodes, one immediately in front of the face and the other at the back. The point effect is then most markedly demonstrated by a darkening of the block at and about the nose. The agar block provides a very convenient means for qualitatively investigating the properties of electrode arrangements especially with respect to intricately shaped objects.

We may sum up by saying that if a knowledge of the temperature distribution in the condenser field is required, we must be satisfied with the results obtained from a simple benzol thermometer which has been suitably designed for maximum sensitivity and minimum disturbing effect in a given set of conditions. The more convenient and more accurate methods of temperature measurement are useless when applied to condenser field investigations. In a great many experiments it might be possible to incorporate the thermometer in the actual dielectric system—a relatively simple matter in the case of a liquid, but if this method is adopted, due regard must be paid to efficient stirring.

(*To be continued.*)

FEBRUARY MEETINGS

Institution of Electrical Engineers

Wireless Section

The next meeting of the above will be held on Wednesday, February 2, at 5.30 p.m. A paper will be given by Professor Willis Jackson, D.Sc., D.Phil., and L. G. H. Huxley, Ph.D., on "The Solution of Transmission Line Problems by use of the Circle Diagram of Impedance."

On Tuesday, February 15, at 5.30 p.m., the meeting will take the form of a Discussion on "Recording and Reproduction of Sound," and will be opened by G. F. Dutton, Ph.D., B.Sc.

On Wednesday, February 23, at 5.30 p.m., a paper will be given by B. J. Edwards, on "A Survey of the Problems of Post-War Television."

Students Section

On Tuesday, February 8, at 7 p.m., the address will be given by the President, Sir A. Stanley Angwin, D.S.O., M.C., T.D., B.Sc. (Eng.), on "Recent Progress in Telecommunications due to the use of new materials."

Electronics Group

At 5.30 p.m. on February 10, in the Rooms of the Royal Society, Burlington House, Piccadilly, London, W.1, the next meeting will be held. A lecture on the "Cyclotron and Betatron" will be given by Professor J. D. Cockroft, the Chairman of the Group.

Association of Scientific Photography

The next meeting of the above will be held on Saturday, February 26 at 2.30 p.m., at the Caxton Hall, Westminster, S.W., and the subject will be "Mass Radiography." Papers will be read by Dr. P. Kerley, F.R.C.P., and Mr. A. L. Cranch, F.R.P.S.

Brit. I.R.E.

A paper will be given by C. E. Tibbs on "A Review of Wide Band Frequency Modulation Technique" at the next meeting on February 24, at 6.30 p.m. This will be held at the Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1.

Additional London Meeting

A special discussion meeting will be held on Wednesday, February 16, at 6.30 p.m., at the Institution of Structural Engineers, 11 Upper Belgrave Street, London, S.W.1. The subject will be "Television Standards" and the discussion will be opened by L. H. Bedford, O.B.E., M.A., B.Sc. (Member) and W. A. Beatty (Member).

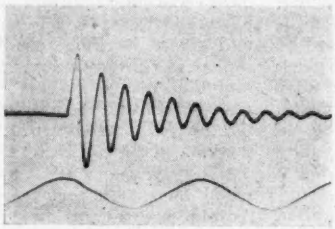
Midlands Section

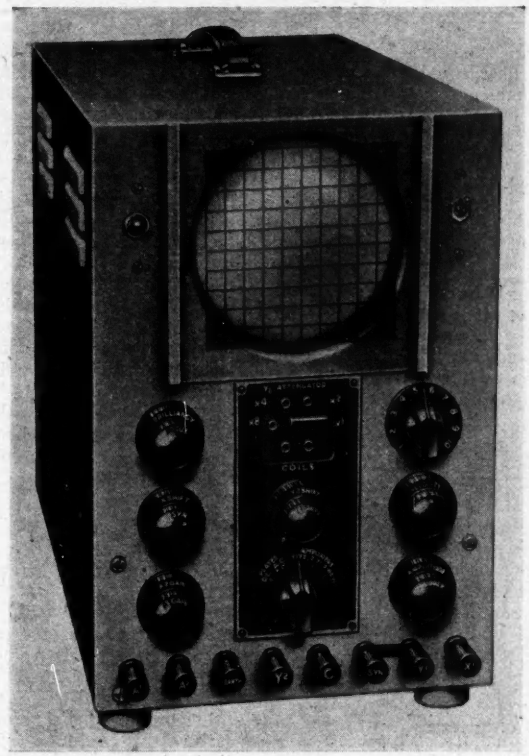
At 6.30 p.m. on Tuesday, February 29, at the University of Birmingham, Mathematics Theatre, Edmund Street, Birmingham, a paper will be given on "Electronics in Medicine" by G. Parr, A.M.I.E.E. (Associate Member).

British Kinematograph Society

The next meeting will be held on February 9, at 6 p.m., at the Gaumont-British Theatre, Wardour Street, London, W.1. A paper will be given by E. D. Eyles, B.Sc., Inst. P., R.P.S., entitled "High-Speed Cameras."

(*Continued on p.* 390.)





COSSOR MODEL 339
DOUBLE BEAM
OSCILLOGRAPH

This is the standard instrument produced to meet the requirements of a wide field of application. It possesses the unique advantage of simultaneous indication of two effects. A 96-page technical Instruction Manual is supplied with each instrument or may be obtained at 3/6. (Postage 3d.).

PRICE £40 NET.

INDUSTRIAL INDICATING & TESTING

THE Cathode Ray Tube has long been established as indispensable in solving technical problems of research and production testing in the radio communications industry, where its use is of course obvious. Not so widely recognized is the fact that it can be equally invaluable in other industries, on both electrical and mechanical tests, when the effect examined is applied to the tube as a voltage.

The inherent value of the Cathode Ray Tube lies in its being the only device capable of providing

VISUAL DELINEATION (as a stationary trace) of the law of variation in recurrent effects.

Accurate RELATIVE TIMING OF EVENTS and other comparative measurements.

As pioneers in the development and application of Cathode Ray technique our outstanding contribution is the DOUBLE BEAM tube, which has the advantage of also providing the important and unique feature of :—

SIMULTANEOUS INDICATION of two variables on a common time axis.

In considering the above in relation to their own particular work, Research and Test Engineers are invited to consult our Instrument Department for expert advice.

A·C·COSSOR Ltd.

Instrument Dept., Cossor House, Highbury Grove, London, N.5

Dust Cores — *A Note by E. R. Friedlaender*

SIR,—Mr. Welsby's comprehensive paper on dust cored coils makes for the first time in this country an effort to give a survey over the whole field, and has certainly raised great interest. Unfortunately, Mr. Welsby has considered the issue mainly from the point of the Post Office engineer, and in particular Part I of the paper contains some statements which cannot go unchallenged.

I believe it to be a mistake to deal at the same time with cores for audio and carrier frequency application on the one hand, and for radio frequency application on the other hand. There are fundamental differences not only in the manufacture, but in the specifications for the two groups which are particularly obvious on Toroid cores. There the Post Office cores contain 95% by volume of magnetisable particles in an annealed state and of relative large particle size, while radio cores are manufactured from hard metal powder of small particle size, the cores containing about 40 to 60% by volume of magnetisable particles.

According to Mr. Welsby's statement there should be no advantage in using high permeability alloys instead of iron in cases in which the insulation increases as much as in the second group, and Mr. Welsby bases this statement on Fig. 1.1 in his paper. On turning up the paper to which he refers it is noted that this curve is only a theoretical illustration of a formula, the limitations of which are not investigated. Actual production experience, however, shows that the employment of high permeability alloys in the radio core group gives distinct advantages. While it is quite appreciated that the differences in permeability are not as high as in the Post Office group, it still can be several per cent. The permeability of radio cores is a compromise between the desired permeability, permissible losses and the required mechanical strength. Even if by the use of high permeability alloys the permeability of the cores is not perceptibly increased in all cases, the other characteristics may be improved considerably. It might be interesting to mention some permeability figures for Post Office Toroids made from :—

(a) Permalloy (annealed) 100 to 120.

(b) Carbonyl iron (annealed) 60.

and for the Toroid cores made from :

Radio frequency material (unannealed) 10 to 20.

I would like to point out that my further remarks will be entirely restricted to radio frequency cores and should be considered as supplementary to Mr. Welsby's comments. From this point of view "specific permeability" and its measurements are of particular interest. It is mentioned that the permeability of a carefully designed Toroidal core is near enough to the actual specific permeability to be considered as such. This is quite correct, but there is no agreed opinion on what a "carefully designed" Toroidal core is. The only definition of such Toroids are found in two British patents. The first one, No. 420,226, granted to H. Vogt and the second is No. 547,187 which has been granted to C. C. Neighbours (Johnson Laboratories.) They do not agree on a single point.

The obvious next question is whether the term "specific permeability" has any practical value. This question must be answered in the affirmative. All firms concerned in core production use the specific permeability as test for metal powder batches. For this purpose every one of the firms concerned has its own specification and this has led to a certain amount of disagreement and the failure to agree on specifications and limits for the powders in question.

A further question will be : Is the term "specific permeability" good enough by itself? Theoretically, it is, of course, quite sufficient to say that the specific permeability of a material is a given figure. This would be the same as to give a tensile strength without linking it up to a specification of the steel—it loses its practical value. How can the term be linked up with the specification in such a way that it becomes a figure of more than theoretical interest?

The first published attempt to do something in this direction has been made by C. C. Neighbours in the cited patent in which he introduced the term "resistancy," which he defines as the ratio between high frequency resistance of a single layer coil with toroidal core and the high frequency resistance of a similar coil wound on a Toroid of the same dimensions manufactured from insulating material. The reference frequency is 1,000 kc/s. I believe that this new term, while interesting, does not quite meet the case. The introduction of the unspecified insulator will introduce new inaccuracies.

Another method is to attach to the specific permeability the guarantee that the losses of the dust core are lower than a standard figure with regard to eddy current losses and hysteresis losses at a given frequency and given working conditions, and higher in resistance across any section and the surface. This specification may be similar to that issued by the G.P.O. for Toroids for Post Office work.

I suggest that there is a very strong case for a national standardised Toroid core test on these lines as, of course, the insulated metal powder can be pressed in many ways to obtain :—

(a) A high permeability by means of higher pressure, thus sacrificing its low loss characteristics, or

(b) Low permeability coupled with very low losses and lower mechanical strength,

or any stage in between these two.

The definition of the " carefully designed" Toroidal cores in the standard would at the same time give a close approach to practical measurement of the "specific permeability."

Let us now go on to Mr. Welsby's description of different core types and his table of their application. One of the first things that comes to our notice is that Mr. Welsby's choice of the word solenoid for the cylindrical core leads him to overlook the obvious misprint in his table. The effective permeability of the cylindrical cores is certainly higher than 1, it normally varies between 1.2 and 3. Cylindrical cores for special application have been manufactured in the U.S.A. which are of considerable length as compared to their diameter, and in such cases the effective permeability has been raised to about 10.

The term "cylindrical cores" usually includes tubular, threaded cores, and cores with brass stems, as long as they are fitted into the coil. The opinion that this type of core is only suited for frequencies over 500 kc/s. is erroneous. Cylindrical cores have their best performance on frequencies below 300 kc/s. in which range (even allowing for the employment of solid wire instead of litz wire) the cored coil will give a satisfactory Q. Other types are advisable only outside the normal long wave range of commercial receivers as in this case the relatively low effective permeability of the cylindrical core makes coils cumbersome and large for still lower frequencies.

The application of cylindrical cores

between 1,500 and 300 kc/s. is purely an economical decision, dictated by the general trend in the development of modern receivers in this country. The cotton reel type core which is discussed below, gives a much superior performance in this frequency range. Between 1.5 and 30 kc/s. the cylindrical core is very often used for inductance trimming purposes only. The lower effective permeability required for this purpose allows for a finer sub-division of the powder particles with a resulting improvement in the magnification factor Q of the complete coil.

The pot-shaped core is ideal for intermediate frequencies in the 450 kc/s. band. It allows for very close screening in this range, but is very expensive and commercially has never been a success in this country. While pot-shaped cores ensure the highest performance in intermediate frequency transformers, a variation of the type has also found special applications in the very low frequencies and very high frequencies. It usually consist of a cotton reel type core in conjunction with a cylinder core which surrounds the coil from the outside.

On very low frequencies it is not chosen for its electrical performance, but for its effective permeability, and its purpose is mainly the reduction of the coil volume, coupled with the possibility of inductance trimming and screening. Too good a performance (too low losses in the core) is not wanted, as it would upset the stability of the circuits by giving too high a Q. A similar type of lower effective permeability is used on very high frequencies for special purposes.

Sufficient attention has not been paid to the first-class performance of the cotton reel type in the 600 to 1,500 kc/s. range which is not mentioned in Mr. Welsby's table. The Q value of a coil provided with a cotton reel core gives a much more even curve over the whole range than any coil with another core. The Q value of such a coil is about twice that of a coil provided with a cylindrical core. It is no wonder that this type has been specially developed and nearly exclusively adapted for this frequency range in Germany, where the receiver design follows the trend of avoiding all possible losses right from the aerial. The cotton reel type, which is more easily manufactured, and is accordingly cheaper, than the pot-shaped core, can be very closely screened and will, as a matter of fact, give a better performance than the latter core. This is particularly true of the type marked "C" in Mr. Welsby's photograph. The core was developed in Germany 1934/5, but is, due to commercial considerations, not very popular in this country.

The *E* and *I* core should be considered as obsolete for radio frequencies as it is well known that the circumference of a rectangular area is longer than the circumference of a round area of the same content, thus increasing unnecessarily the copper losses in the first case. A core type known as half iron-clad (a variation of the pot-shaped core) should be used instead.

The following table contains my suggestions for the application of radio frequency cores. The best choice gives cores of best electrical performance, the second choice gives the next best and the commercial choice gives the usual commercial application.

Just as a matter of interest it might be mentioned that the first dust cores were not made in 1915, but by Oliver Heaviside, who, examining the mutual inductance between coils, described dust cores in 1887. British patents for the use of iron cores for wireless purposes were granted to the American, John Stone, in 1902 and 1904. The first commercial application was in 1904 in which year Marconi provided their A55 (3,000 kc/s. amplifier with a dust cored, permeability-tuned (!) intervalve transformer.

E. R. FRIEDLAENDER.

Frequency	Best Choice	Second Choice	Commercial Choice	Remarks
150 KC.	Reel core with outside cylinder	—	Reel core with outside cylinder	Chosen on account of high permeability to reduce copper losses in winding. Material which increases Q of coil not wanted.
150–400 KC.	Cylindrical core	—	Cylindrical core	
I.F. (450 KC.)	Pot core	Reel core	Cylindrical core	
600–1500 KC.	Reel core	—	Cylindrical core	
1.5 MC.	Cylindrical core Reel core with outside cylinder	— —	Cylindrical core Reel core with outside cylinder	Specially designed shapes and reduced permeability to reduce losses. Reel core for screening with outside cylinder. Cylindrical core mostly for trimming (threaded core).

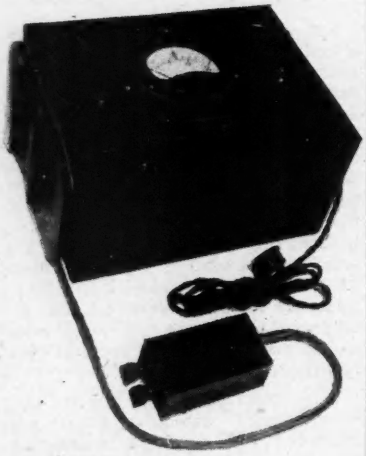
Reply by V. G. Welsby

SIR,—As far as fundamental theory is concerned, all dust cores of whatever material, whether intended for audio, carrier or radio frequencies, are the same in that they consist of particles of magnetic material of various shapes and sizes, separated by layers of non-magnetic insulation. bearing this in mind, I cannot agree that there is any necessity for treating l.f. and h.f. cores separately. In the article I was dealing with the properties of dust core materials. Manufacturing methods were outside the scope of the article and were mentioned mainly from the point of view of historical development.

It is unfortunate that the wording of my brief statement about permeability was somewhat misleading. It was stated, quite justifiably, that Fig. 1.1 merely "gave some idea of the dependence of μ on μ_0," and it was intended to indicate how, as the relative volume of insulation in a core is increased, the more and more nearly its specific permeability is independent of the permeability of the material of which the particles are composed.

The definition of specific permeability also seems to have caused some misunderstanding. It should be clearly understood that the specific permeability, as defined, is a fundamental property of a dust core *material*, and has nothing to do with the shape of the core. (It is, in fact, the permeability of the material, assumed homogeneous, defined in the same way as that of any other ferro-magnetic substance.) It is extremely difficult to measure the specific permeability of a material except by forming it into a uniform closed circuit such as a toroid, but it will be realised that the permeability so measured is of importance in the design of cores of other shapes using the same material.

The next point which arises is the specification of a suitable test coil for permeability measurements. The analysis for the general case of a toroid of any cross-section is somewhat involved, but we can attack the problem by considering the particular cases of circular and rectangular cross-sections, and then assuming that all practical cases lie within these two extremes. If the cross-sectional area of the core is A_m and it is wound with a uniform, single-layer winding so that there is a space of cross-sectional area A_s between core and winding, the inductance of such a coil is given by:



DIODE VOLTMETER

type 281

5 Ranges 0–1.5, 5, 15, 50 and 150 volts.

Accuracy ± 2½%

Frequency range 50 c/s to 50 Mc/s

Stabilised self contained power supply for a.c. operation.

PRICE £50

Write for detailed particulars

P.S. *A few type 741 Signal Generators are still available for immediate delivery.*

FURZEHILL

LABORATORIES LTD.

BOREHAM WOOD

HERTS

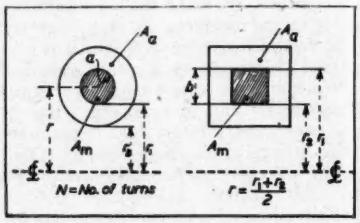
TELEPHONE · ELSTREE 1136

DUST CORES : *Mr. Welsby's Reply (contd.)*

$$L = \frac{4N^2[A_a + A_m(\mu - 1)]}{2r_{ett}} \cdot 10^{-9}$$

henry.

where μ is the specific permeability and r_{ett} is the effective radius of the core (There should be an additional term representing the inductance of a single loop of radius r_{ett}, but this is negligible in any practical case.) The effective radius is given by:—



$$r_{ett}\ \text{(circular)} = r\left[1 - \tfrac{1}{4}\left(\frac{a}{r}\right)^2 + \frac{1}{16}\left(\frac{a}{r}\right)^3 \cdots\right]$$

$$r_{ett}\ \text{(rectangular)} = r\left[1 - \frac{1}{12}\left(\frac{b}{R_2}\right)^2 - \frac{1}{12}\left(\frac{b}{R_2}\right)^4 \cdots\right]$$

It is easy to show that the error involved in taking $r_{ett} = r$ is not normally very great; for example, if the radial thickness is not more than a third of the inner radius, the error is only of the order of 1%. This being so, it is possible to specify our test coil in such a way that the error is negligible and the flux-density can be taken as constant over the cross-section of the core.

Then:—

$$L \doteqdot \frac{4N^2[A_a + A_m(\mu - 1)]}{2r} \cdot 10^{-9}$$

henry.

As a final word of explanation, it may be pointed out that a dust core *material* can be defined, as far as the magnetic properties are concerned, by its specific permeability, together with its fundamental loss coefficients, e, a, c. These parameters are mainly of interest to the core manufacturer who has to select the particle material, size of particle, amount of insulation and binder, moulding pressure, etc., so as to obtain the desired values. Corresponding to these are the effective permeability and the secondary loss factors F_e, F_h, F_c, which define characteristics of the *complete core*. It is the latter which concern the user of the core, who is not directly interested in manufacturing processes. The fundamental loss coefficients are measured by means of test toroids of the same type as would be used for measurement of specific permeability. Although such test cores and windings merely require to meet the conditions implicit in the above equations, it would be useful if a universally approved standard could be specified. These various quantities are not merely of academic interest, since it is possible to establish relationships, either theoretically or experimentally, between the fundamental parameters and the manufacturing details, and between the secondary parameters of complete cores and the fundamental ones of the material.

The misprint in Table 1 of Part 1 was not due to any confusion of terms, since a dust-cored coil with a permeability of 1 would not be very much use. It is agreed, however, that the term "cylindrical" when applied to cores is probably preferable, although I still prefer "solenoidal" coils.

Although, as Mr. Friedlaender points out, the Q attained with pot-type cores in the 450 Kc/s. band may be too high for radio receiver purposes, it should be made clear that they are often used at such frequencies in apparatus such as filters in which the highest possible Q values are required.

In conclusion, I should like to thank Mr. Friedlaender for the interest he has taken in this matter.

V. G. WELSBY.

Meetings. (*Continued from page* 386.)

Television Society

The Annual General Meeting (Members only) will be held at the Institution of Electrical Engineers on Saturday, February 5, at 2.30 p.m.

This will be followed by a paper by P. Nagy (Fellow) on: "The Signal Converter: A new deflection modulated Cathode-Ray Valve, and its Application to Television," at 3.15 p.m., to which visitors are invited.

Books reviewed on page 394 or advertised in this Journal, can be obtained from

H. K. LEWIS & Co. Ltd.

136 Gower Street, W.C.1

If not in stock, they will be obtained from the Publishers when available

NOTES FROM THE INDUSTRY

A Radio Musuem in a Window. The display of Mr. Paul Taylor of Kettering showing receivers that have been handled in the past twenty years, which form part of his museum collection.

New Year Honours in the Industry

Congratulations to Mr. E. G. Bailey, Works Director of the Metropolitan-Vickers Electrical Co., on his knighthood, together with Mr. A. H. Railing, Chairman of the G.E.C.

Another name in the New Year's Honours List which is of interest to the industry is that of Mr Oliver Simmonds, who receives a knighthood.

Among the products of the Simmonds Companies now well known in the electrical industries are Simmonds' nuts, remote controls and electronic instruments, and other accessories of novel conception.

Mr. W. F. Bishop, Director of Messrs. W. T. Henley's Telegraph Works Co., Ltd., and Chairman of the Cablemakers Planning Committee, is appointed a Commander of the British Empire.

M.B.E.s include Mr. A. V. Allday, the factory manager of the Gramophone Co., Mr. N. C. Robertson, director and general manager of Messrs. E. K. Cole, and Mr. A. Speight, works superintendent of the A.T.E. Co.

Numerous employees receive the British Empire Medal for meritorious service, including Miss Joan Ball, capstan operator at E. K. Cole, Mr. F. Connors, turner at Met.-Vick. and Mr. H. Taylor, foreman of the silica valve production at Mullards.

New R.S.G.B. President

Mr. E. L. Gardiner, B.Sc. (G6GR), was installed as President of the Incorporated Radio Society of Great Britain at a meeting of the Society held at the Institution of Electrical Engineers, London, on Saturday, January 29, 1944.

The use of C.R. Tubes in Equipment

B.S.I. Recommendation

The new British Standard Code of Practice, B.S.1147:1943, gives the recommendations of a representative cathode-ray tube manufacturers committee on the conditions to be observed by designers to ensure optimum performance and life from the tubes.

The recommendations cover mounting, heater-voltage regulation, heater-cathode insulation, and circuits in conjunction with the tubes.

Some useful general notes include the suggested use of a filter of the same colour as the trace in front of the screen to minimise the effect of stray light on the face of the tube. It is also pointed out that the effects of the earth's field are of particular significance in the case of mobile equipment.

Copies of the Code can be obtained from the British Standards Institution, 28 Victoria Street, S.W.1, price 6d. net, post free.

T.E.M.E.

The Telecommunication Industry, which has been in existence for over fifty years, has a sound claim to a thoroughly representative Trade Association of its own, whether that claim be based on the volume of capital invested, the permanent employment afforded to skilled and unskilled workers of both sexes, on the volume and potential expansion of its export trade, or on the importance, especially under present circumstances, of having available for the guidance of Government Departments a source of accurate knowledge and information on all questions affecting a specialised industry of this kind.

A Telecommunication Engineering and Manufacturing Association has been formed to promote the interests of the Industry, to maintain the highest possible standard of telecommunication equipment and to facilitate, whenever required, collaboration with Government Departments on matters of national concern.

The offices of the Association are at Aldine House, 10, Bedford Street, Strand W.C.2.

Vacuum Science Products

Change of Name

The firm Vacuum Science Products, Ltd., of Norwood Junction, S.E.25, have now changed their name to Radio Electronics Limited (Proprietors—County Commercial Cars Limited). This concern is at the moment devoting its chief activities to the manufacture of photo-cells and various types of caesium and rubidium photo-electric multipliers.

The registered office has been transferred to 121, Albert Street, Fleet, Aldershot, Hants. The works remain as before at Norwood.

Institute of Physics

Conference on X-ray Analysis

The third Conference on "X-Ray Analysis in Industry" has been provisionally arranged to take place in Oxford on March 31 and April 1, under the auspices of the X-Ray Analysis Group of the Institute of Physics. Details will be circulated shortly to members of the Group and will be sent to non-members on application to Dr. H. Lipson, F.Inst.P., Hon. Secretary of the Group, c/o Crystallographic Laboratory, Free School Lane, Cambridge. The conference will be open to all interested, but it may be necessary to limit the number of non-members of the Group for whom accommodation can be provided.

ABSTRACTS OF ELECTRONIC LITERATURE

MEASUREMENT

An X-Ray Output Meter
(J. E. Roberts and F. T. Farmer)

The basis of the instrument described is an ionization chamber fitted into the tube aperture through which the rays pass. The current through the chamber, when saturation is maintained in it, is a measure of the intensity of the X-ray beam. A method is put forward whereby the intensity can be read directly. The chamber was designed specifically for a Metro-Vick tube of the continuously-evacuated type. The meter is claimed to provide a valuable degree of protection to the X-ray operator by giving him an instantaneous reading whenever the shutter is open.

—*Br. Jnl. Radiology*, Nov., 1943, p. 353.*

A Wide-Band Oscillograph
(E. D. Cook)

The development of a wide-band oscilloscope intended for use as a precision-measurement tool is described. The means by which the performance specifications were determined are outlined and the construction of the oscilloscope is described in detail. The theory of operation of certain components is examined.

—*Proc. I.R.E.*, Aug., 1943, p. 410.*

CIRCUITS

A Variable-Frequency Electronic Generator
(D. A. Griffin)

An electronic generator has been designed to deliver a power output of 1,400 watts over a frequency range of 300 to 3,500 c/s. The frequency stability is reported to be better than 2 per cent., and the waveform substantially sinusoidal under normal operating conditions. A novel automatic control circuit keeps the regulation within 1 per cent. for output voltages between 85 and 125 volts. A number of applications are mentioned and space is devoted to mechanical design.

—*Electronics*, Sept., 1943, p. 130.

Electronic Voltage Regulators
(F. L. Hogg)

It is shown that published formulae for electronic voltage regulators are inapplicable without considerable information on the valves to be used, so that direct measurements may have to be taken. The basic regulator circuit and its developments are discussed and by an elaborate system of tabulating data, a design is worked out to suit specified conditions. The importance of the design of the potential divider is emphasised and demonstrated by numerical examples. Space is devoted to the effects of voltage and current compensation.

—*Wireless World*, Sept., 1943, p. 327.*

Single-Valve Frequency Divider
(P. F. Cundy)

Theoretical and practical work is described, demonstaring the analogy between negative transconductance and multivibrator oscillators, and how the latter may be used as a frequency divider. An account is given of the operation of an untuned Herold oscillator, including methods of injecting the synchronising signal. It is pointed out that whilst a multivibrator functioning as a divider requires three valves per dividing stage, the number in the system shown is reduced to one.

—*Wireless World*, Sept., 1943, p. 335.*

The Frequency Synthesiser
(H. J. Finden)

This paper describes a frequency synthesiser which enables any frequency that is harmonically related to a sub-multiple of a standard frequency to be generated by means of a decade system involving a synthesis process. The adjacent harmonic interference is substantially independent of the order of the harmonic and can be extremely small.

The paper is divided into two parts. The limitations of the present technique as applied to frequency measurements and the means of overcoming them are given in Part (1), while Part (2) outlines the principles of the frequency synthesiser and gives a detailed description of a typical example with some applications of its uses as a source.

—*J.I.E.E.*, Vol. 90, Pt. 3 (1943), p. 165.

An Improved Current Integrator
(J. Morris Blair)

An improved integrator circuit for measuring the ion beam current used in nuclear research is described. A condenser is allowed to be charged and upon reaching a definite potential is discharged through a thyratron tube. This action is brought about at the proper point by a trip circuit composed of two pentode tubes. The potential between the thyratron cathode and the trip circuit is accurately controlled by a voltage regulator network. The action of the circuit proves to be quite linear over a wide range of currents and rates of operation.

—*Rev. Sci. Inst.*, Vol. 14 (1943), p. 64.

INDUSTRY

Tests of Thermoplastics for Electrical Applications
(E. K. Cliver)

An account is given of the testing methods and equipment employed by the American Society for Testing Materials for the purpose of deriving the published mechanical and electrical properties of cellulosic and other plastics. It is considered that only tests on the finished equipment can confirm the applicability of a plastic for any particular use. There is no A.S.T.M. method for testing the corrosive effects of plastic materials, and additional tests described in this respect are not standardized.

—*El. World*, Oct. 16, 1943, p. 60.

Toroidal Winding Machines
(F. E. Planer)

The paper describes the principle of operation and the construction of automatic machines for applying wire or tape, etc. on to toroidal or other types of cores in which winding material cannot be fed past the winding axis and where the core has to remain stationary with regard to this axis. A graphical method is derived enabling the construction of polar diagrams of ring velocities for machines in which the winding material is carried on a ring enclosing the core. Conclusions drawn from these diagrams bearing on the design and operation of machines for particular applications are discussed

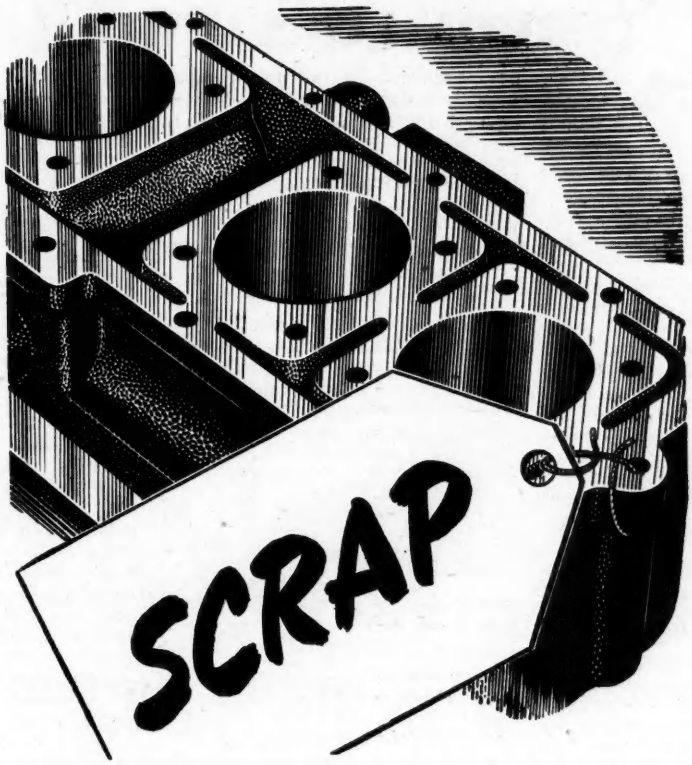
—*Jour. Sci. Inst.*, Vol. 20, 1943, p. 185.

Microradiography of Light Alloy Spot Welds
(S. T. Gross, G. L. Clark)

The differences between macroradiography and microradiography are indicated, in microradiography the specimen being very thin and the X-ray beam being of carefully selected wavelength. A special photographic film with a very fine-grained or Lipmann emulsion is required so that the photograph obtained can be enlarged up to 300 diameters without loss of essential detail due to graininess of the film. The application of microradiography to the examination of aluminium and light alloy spot welds is discussed with the aid of photographs.

—*Iron Age*, 22/7/43, p. 44.*

* Supplied by the courtesy of Metropolitan-Vickers Electrical Co. Ltd. Trafford Park, Manchester.



A METAL CASTING — perfect in design, of valuable material, and important to war production — yet it is thrown on the scrap heap. Why? — *because of porosity.*

Waste of material, waste of labour, waste of man hours.

But now a really efficient remedy has been discovered in *Bakelite Sealing Solution*, containing the resinoid which is the basis of Bakelite Plastics. Forced into the pores of the faulty casting, solidified there by baking, this solution renders previously porous metal completely resistant to lubricating oils, alcohol, aviation spirit, cold or boiling water, steam — even to temperatures as high as 600°F. This process, of highest national importance in wartime, is extremely simple and requires neither special apparatus nor skilled labour.

This is just one of the indirect ways in which Bakelite Limited are helping the war effort. Manufacturers who are interested should write for details.

BAKELITE LIMITED, 18 GROSVENOR GARDENS, LONDON, S.W.1

TREFOIL

BAKELITE PLASTICS

REGD. TRADE MARKS

Pioneers in the Plastics World

G2782

BOOK REVIEWS

Time Bases

(Scanning Generators)
O.S. Puckle 204 pp. 124 figs. (Chapman & Hall, 16s. net.)

This book is based on a paper read before the Institution of Electrical Engineers under the same title, but the author has considerably expanded certain parts of the subject matter.

After an introduction which incorporates historical notes, the four main chapters are preceded by a discussion of scanning waveforms. The circuit descriptions are grouped under types of time base; trigger circuits, blocking and inductive time bases, and polar, multiple and velocity modulation time bases. Many of the arrangements described have received little attention previously, and practically every circuit of use is mentioned.

Linearisation, push-pull deflection, and synchronising are discussed in the following chapters, and the main text concludes with a most interesting reference to frequency division.

The usefulness of the book by no means ends at this point, as there are seven appendices which present a great deal of information which has not previously appeared in collated form. That dealing with gas-discharge triodes will be new even to those having considerable experience of these valves in time-base circuits. As one might expect from the author, the first appendix explaining the cathode-ray tube and its aberrations is written in exemplary style and the only criticism is that the treatment of trapezium distortion is a little less adequate than that of other aspects of the subject.

The book contains a complete list of references to original sources, together with a bibliography and index.

There can be little doubt that this book will remain a standard work on scanning generators for some years, and the general arrangement and illustrations are in keeping with the uniformly high standard of the text. There is a commendable absence of errors of any sort throughout.

T.D.H.

Basic Calculations For R.A.F. Ground Duties.

A. E. Druett. 52 pp. (Sir Isaac Pitman & Sons, 3s. 6d. net.)

This is a training manual for the Radio and Electrical Trades in the R.A.F. and is also suitable for Air Corps Cadets. A similar manual is available for fitter trades.

It covers fractions, decimal fractions, indices, British and Metric units, percentages, and formulae. The second part of the book deals with the measurement of angles, the circle, and simple problems in right-angled triangles Each chapter has a set of test questions appended and the answers are given in fair detail at the back of the book. It should prove a useful adjunct to the training classes in the subject.

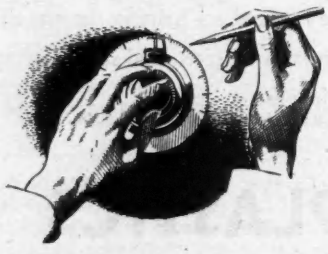
Electromagnets and Windings.

G. Windred 102 pp. (Geo. Newnes, 10s. 6d. net.)

Intended primarily for engineers interested in the design of electromagnets, this book is also of interest to students, as the practical design of electromagnet windings is usually omitted from the electrical engineering course. The three main chapters deal with tractive magnets, solenoid magnets, and the design of windings, and there is also a chapter on operation and testing. Typical designs for D.C. and A.C. solenoids are given together with fundamental winding calculations. In the chapter on testing there are suggested circuits for coil turns checking and short-circuited turn detection. Various wire tables and data are inserted in the text.

This is a well-written and interesting book on a specialised subject and is worthy of a place in all college and works libraries.

The story behind the scale



★ How precise itself must be the means of measuring precision! In Radio the means implies Marconi instruments, of many types specifically designed to measure precise performance in communication equipments.

The last graduation on a calibrated dial is the finishing touch to a Marconi instrument; a meticulous operation, but not more so than the many preceding it. For behind this work—back to the very birth of wireless communication—is a tradition of skill and workmanship.

The complete answers to questions of measurement are found entirely within the Marconi organisation. That is why such a diversity of instruments is produced to meet many and increasing requirements. Our activities are centred around this specialised work—perhaps already we have anticipated *your* particular problem.

MARCONI Instruments Ltd

ELECTRA HOUSE · VICTORIA EMBANKMENT · W.C.2

HEAT RESISTING

The toughness of his feet is all the insulator he requires, but if you need a low loss insulator which will stand up to 400°C yet is still readily machinable—what is there but MYCALEX?

Power Factor 1 meg. and over .002	Tensile Strength lbs./sq. in. 5,800
Permittivity 6.7	Water Absorbtion NIL
Electric Strength (volts/mil.) 550	Plastic Yield ... 450°C.

Send for illustrated brochure

MYCALEX COMPANY LIMITED • CIRENCESTER • GLOS.

SPOT ON! Anywhere between 10 and 3,000 Metres

You must be right on the mark at once these days. That's why so many Redifon 605 Wavemeters are in service. They are accurate, reliable and very compact. A few are available for priority users. Prices on application.

- *Valve voltmeter indication.*
- *Eight coil ranges for 100 KC's to 42 MC's.*
- *Dimensions 9" x 5" x 7".*
- *Built-in long life batteries.*

REDIFFUSION LTD

Designers and manufacturers of Radio Communication and Industrial Electronic Equipment

REDIFON

A SUBSIDIARY OF BROADCAST RELAY SERVICE LIMITED

VICTORIA STATION HOUSE • VICTORIA STREET • LONDON • S.W.1 (PHONE VICTORIA 8831)

GALPINS ELECTRICAL STORES

"Fairview" London Road, Wrotham, Kent.

TERMS: Cash with order. No C.O.D.

Regret no Orders can be accepted from Eire or Northern Ireland.

ELECTRIC LIGHT CHECK METERS, well-known makers, first-class condition, electrically guaranteed, for A.C. mains 200/250 volts 50 cy. 1 phase 5 amp. load, 10/- each.

HEAVY DUTY CABLE, V.I.R., and braided, in first-class condition, size 37/13, lengths 30 to 40 yards. Price by the length, 5/- per yard.

ROTARY CONVERTER, D.C. to D.C., input 48 volts; output 2,500 volts at 1 kW., condition as new. Price £10, carriage paid.

½ WATT WIRE END Resistances, new and unused, assorted sizes (our assortment), 5/6 per doz.

SOLID BRASS LAMPS (wing type), one-hole mounting, fitted double contact small B.C. holder and 12-volt 16 watt bulb, 3/6 each, post free.

TUNGSTEN CONTACTS, ¼ in. dia., a pair mounted on spring blades, also two high quality pure silver contacts 3/16 in. dia., also mounted on spring blades, fit for heavy duty, new and unused; there is enough base to remove for other work. Price the set of four contacts, 5/-, post free.

MASSIVE GUNMETAL WINCH for use with ¼in. solid steel wire, worm and wheel, complete with long handle, weight 50 lbs. Price £3, carriage paid.

MOVING COIL AMPMETERS, 2½in. dia., panel mounting, modern type, reading 0–½ or 0–20 amp. (state which required), F.S.D., 15 M/A., 30/- each.

ROTARY CONVERTOR. D.C. to A.C., input 22V. D.C. (twenty-two), output 100 volts at 140 M/A., 50 cycle. single phase, ball bearing, in first-class condition, no smooching. Price £3 carr. paid.

RADIO BOOKS

CATHODE RAY OSCILLOGRAPHS

By J. H. Reyner, B.Sc.(Hons.), A.C.G.I., D.I.C., etc. An easily assimilable guide to the practical application of cathode-ray tubes to numerous purposes, including the examination of oscillations or wave-forms. Has been given the highest recommendations both for students or teachers. Second Edition. 8s. 6d. net.

ELEMENTARY HANDBOOK FOR WIRELESS OPERATORS

By W. E. Crook. An up-to-date book presenting a general view of radio communication with an introduction to its technique. It gives all the information necessary for a complete understanding of the subject in a clear and easily assimilable manner, with profuse diagrams. Second Edition. 4s. net.

ACCUMULATOR CHARGING MAINTENANCE AND REPAIR

By W. S. Ibbetson, B.Sc., A.M.I.E.E. A comprehensive and practical treatment of the subject. It is filled with highly-compressed, but clear, information and in it the ordinary user will find everything he needs to know about the charging and upkeep of accumulators for all purposes. Eighth Edition. 6s. net.

Some of the books advertised may be temporarily out of stock when you place an order. If you have any difficulty in securing copies of Pitman Books through your bookseller, write to Enquiry Department, Pitman House, Kingsway, London, W.C.2. Please do not send money when making enquiries.

39 PARKER ST., KINGSWAY, W.C.2

PITMAN

Classified Announcements

The charge for miscellaneous advertisements on this page is 12 words or less 3/-, and 3d. for every additional word. Single-column inch rate displayed, £1. All advertisements must be accompanied by remittance. Cheques and Postal Orders should be made payable to Hulton Press, Ltd., and crossed, and should reach this office, 43, Shoe Lane, London, E.C.4 not later than the 15th of the month previous to date of issue.

FOR SALE

IN STOCK, Rectifiers, Accumulator Chargers, Rotary Converters, P.A. Amplifiers, Mikes, Mains Transformers, Speakers of most types, Test Meters, etc., Special Transformers quoted for.—University Radio, Ltd., 238, Euston Road, London, N.W.1. Ger. 4447.

LOUDSPEAKERS

LOUDSPEAKERS—We carry on. Sinclair Speakers, 170, Copenhagen Street, N.1.

LOUDSPEAKER repairs, British, American, any make, 24-hour service; moderate prices.—Sinclair Speakers, 170, Copenhagen Street, N.1.

MISCELLANEOUS

WE WILL BUY at your price used radios, amplifiers, converters, test meters, motors, pick-ups, speakers, etc., radio and electrical accessories. Write, phone or call, University Radio Ltd., 238, Euston Road, London, N.W.1. Ger. 4447.

WEBB'S Radio Map of the World enables you to locate any station heard. Size 40" by 30" 2 colour heavy Art Paper, 4/6, post 6d. Limited supply on Linen, 10/6, post 6d.—Webb's Radio, 14, Soho Street, London, W.1 'Phone: GERrard 2089.

MORSE Practice Equipment for Class-room or Individual Tuition. Keys, Audio Oscillators for both battery or main operation. Webb's Radio, 14, Soho Street, London, W.1 Phone: GERrard 2089.

SITUATIONS VACANT

A.M.I.E.E., City and Guilds, etc., on "NO PASS-NO FEE" terms. Over 95% Successes. For full details of modern courses in all branches of Electrical Technology send for our 112-page handbook—FREE and post-free. B.I.E.T., (Dept. 337B), 17 Stratford Place, London, W.1.

RADIO SALES ASSISTANT required for Central London Short-wave shop. Send full particulars of age, experience and salary reqd. to Berry's (Short Wave) Ltd., 25, High Holborn, W.C.1.

SITUATION WANTED

COMMUNICATIONS ENGINEER requires administrative post. Twelve years experience of design, development and production of transmitters, receivers and precision measuring equipment. Fully conversant with the requirements of Government departments. Referees well known in the industry. Box No. 673. "Electronic Engineering."

WANTED

WE OFFER cash for good modern Communication and all-wave Receivers.—A.C.S. Radio, 44, Widmore Road, Bromley.

HIGH FREQUENCY Eddy current Generator 3 to 5 KW., new or secondhand, required for high vacuum laboratory. Please send particulars to Box EE/P, c/o "Scientific," Cliffords Inn, London, E.C.4.

FOYLES

BOOKSELLERS TO THE WORLD

Nearly 3,000,000 new and Second-hand Books on Engineering and every other subject.

Books Bought.

119-125 Charing Cross Road, London, W.C.2

Tele: Gerrard 5660 (16 lines). Open 9-6 Inc. Sat.

Makes 30 important tests, 100 to 750 volts. A.C. or D.C. Ideal for Radio Engineers. From Wholesalers or direct. Send for Leaflet L24

RUNBAKEN·MANCHESTER·1

ELECTRADIX

POWER TRANSFORMERS. Single phase 50 cycles 35. KVA. 35,000 watts, by Brit. Elec. Transf. Co. 220 volts to 110/110 volts, **£30.** 5 KVA 220 volts to 5,000 volts and 500 volts, **£10.** 2 KVA Foster 200 volts to 4,000 volts, **£8 10s.** 1½ KVA Zenith 100 volts to 6,000 volts, **£8.** 3 KVA 400 volts SP 50 cycles to 600 volts, oil filled, by Metvick, **£9.** All as new.

TRANSFORMER COMPONENTS. Stampings Control limits supply. We offer some 100-watt transformers for rewinding. Complete, good class but unknown ratios. Sold for re-making, **22/6.** Larger 250-watt size, **27/6. Stalloy Sheets for Transformer Stampings,** 38 in. × 6 in., 1/3 each.

PUMPS. Stuart Motor Pumps, centrifugal, C.D. Shelter, 12 volts D.C. or 230 volts A.C. In stock. Twin-piston pumps with or without motors, for suds or water.

DRILLS. Electric Bench Drills, D.C. Wolf, 110 volts, massive pillar type, geared feed, counter weight rise, No. 1 morse socket for 2 in. steel. For delivery without permit. **£8/10/-** each.

PORTABLE ELECTRIC DRILLS. D.C, 110 volts, **£5 10s.** A.C., 220 volts, **£7 10s.**

6 MERCURY VAPOUR LAMPS, 400-watt Phillips "Philors," with chokes, condensers, lampholders and 20 in. Reflectors, for sale singly or as one set.

MOTORS AND DYNAMOS. We have acquired a useful parcel of D.C. Motors in all sizes from 1/8th H.P., 1/6th, 1/4th, 1/3rd, ½, ¾, 1, 1½, 2, 3, 4, 5 and 6 H.P., in 110, 220 and 440 volts. There are also a number of A.C. Motors, single and 3-phase, from 1/8th H.P. to 3 H.P. Kindly specify wants and we will offer the nearest.

BLOWERS AND FANS. Exhaust and open type of 1/6th to 6 H.P. available.

COVERS. Light Metal ventilated covers for test boards, resistances, chargers, etc., special arch-shape to contain 6½ in. × 5 in., with terminal cover extension, 3/6.

Please send stamped envelope for answer to enquiries and include postage for mail orders.

ELECTRADIX RADIOS

214, Queenstown Road, Battersea, London, S.W.8

Telephone: Macaulay 2159.

Ode

Partridge No. 27

Don't Transmit

Now is the time of coughs and colds,
Of "snuffles" and of sneezes,
You may receive, but don't transmit
These germs and spread diseases.

If you drop a note in output
Plus an oscillating head
'Tis a sign of low resistance,
Germs are busy—get to bed!

Microphonic noises haunt you,
Tubes are blocked, you nearly choke,
Joints are dry your chassis' aching,
Speech coil's jammed, your words a croak.

Germs are just like radio signals,
Unseen, silent, till they find
Sympathetic tuned receivers—
Folk whose health is undermined.

Control the volume of this scourge
By perfect insulation,
Then when dead end effect has passed,
Get back in circulation.

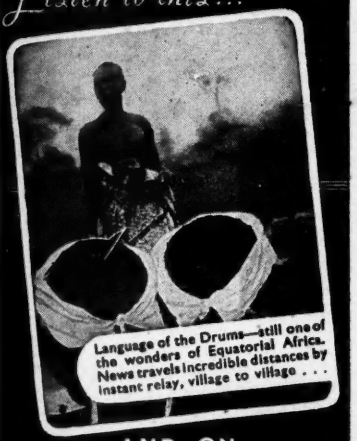
N. Partridge

Ph.D. B.Sc., M.Brit.I.R.E., M.I.E.E.

Transformer Manufacturers,

76-78, PETTY FRANCE, LONDON, S.W.1. *Telephone:* ABBey 2244.

Listen to this...



Language of the Drums—still one of the wonders of Equatorial Africa. News travels incredible distances by instant relay, village to village . . .

AND ON THE FACTORY FRONT

Trust TRIX

Quality SOUND *Equipment*

THE TRIX ELECTRICAL Co LTD
85, BOLSOVER STREET, LONDON, W. I.

AFTER THE WAR!

The advance in Radio Technique after the war will offer unlimited opportunities of high pay and secure posts for those Radio Engineers who have had the foresight to become *technically qualified*. How you can do this quickly and easily in your spare time is fully explained in our unique handbook.

Full details are given of **A.M.I.E.E., A.M.Brit.I.R.E., City and Guilds Exams.** and particulars of up-to-date courses in **Wireless Engineering, Radio Servicing, Short Waves, TELEVISION, Mathematics,** etc., etc.

Prepare for to-morrow's opportunities *and post-war competition* by sending for your copy of this very informative 112-page guide NOW—**FREE.**

British Institute of Engineering Technology
(Dept. 337a) 17, Stratford Place, London, W.1.

Varley for Victory

Our products at present are for "Priority" demands.

For Peace, we will bring you new designs, incorporating the experience of 40 years as manufacturers of high-class products.

OLIVER PELL CONTROL LTD.

CAMBRIDGE ROW, BURRAGE ROAD, WOOLWICH, LONDON, S.E.

Varley for Peace

over-reached—

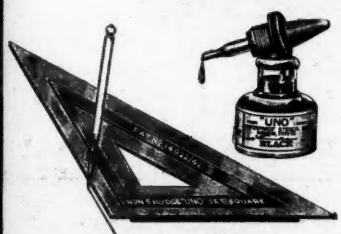
Greedy people usually do over-reach, and when it's certain they can neither grab the prize nor climb back to safety—how they squeal!

The prize belongs to the Allies. When they have plucked it, we will again quickly switch back to our peace-time productions.

Meanwhile we are still willing to assist you on any variable resistance problem vital to the war effort.

RELIANCE
Manufacturing Co. (Southwark) Ltd.
Sutherland Rd.. Higham Hill, Walthamstow, E.17.
Telephone—Larkswood 3245

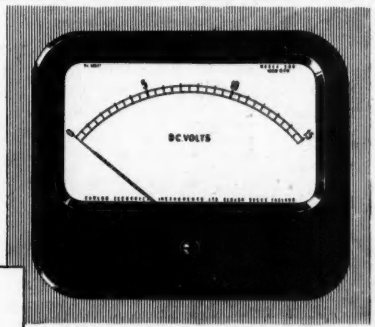
"UNO" STENCILS



6 Stencils of Electrical Symbols 6/- each

A. WEST & PARTNERS, LTD. 36, BROADWAY WESTMINSTER, S.W.1

A TAYLOR FAMILY



MODEL 500
5" scale.
Size 6½" × 5¼"

MODEL 400
4" scale
Size 4⅞" × 4⅛"

MODEL 350
3½" instrument type.
Flush or Projecting.

These moving coil instruments are very soundly constructed, and are accurate and dependable in use. A very large number of ranges are available in moving coil, Rectifier and Thermocouple type instruments.
Model 400 and 500 instruments are also available with illuminated dials.
All models are supplied in black moulded insulated cases, and Alnico magnets and stainless iron polepieces and cores are used.

We also manufacture several other sizes of moving coil instruments with scales of 2" and up.

Taylor electrical instruments ltd

Send your enquiries to

TAYLOR ELECTRICAL INSTRUMENTS, LTD.,
419—424 Montrose Avenue, Slough, Bucks.

Telephones: Slough 21381 (4 *lines*). *'Grams:* "Taylins, Slough."

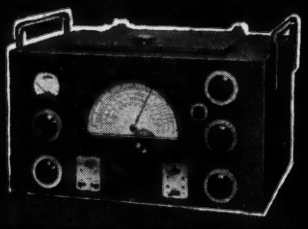
Printed in Great Britain by The Press at Coombelands, Ltd., Addlestone, Surrey, for the Proprietors and Publishers, Hulton Press, Ltd., 43-44, Shoe Lane, London, E.C.4
Sole Agents for Australia and New Zealand: Gordon and Gotch (A/sia), Ltd. South Africa: Central News Agency Ltd.
Registered for Transmission by Canadian Magazine Post.

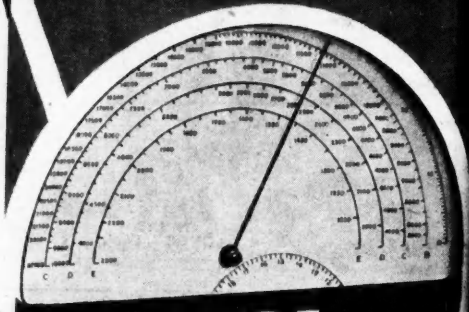
EDDYSTONE "358X" COMMUNICATION RECEIVER.

Specification: The receiver employs one stage of R.F. amplification, frequency changer, two I.F. amplifiers, a separate beat frequency oscillator, octal base Mullard or Osram 6.3 volt valves. Frequency range is continuous from 22 Mc/s. to 1.25 Mc/s. using four fully screened interchangeable coil units. Five additional coil units extend the range to 31 Mc/s. and 90 Kc/s. Illuminated dial is accurately calibrated with four standard coils. Additional coils supplied with separate graph. To simplify maintenance a meter and test switch is fitted. Main tuning control incorporates flywheel drive and spring loaded Tufnol gearing (ratio 70—1). Logging scale supersedes the old type bandspread control. Separate power unit assures freedom from drift. Incorporates Band Pass Crystal Filter unit, selectivity 300 c/s. or with crystal gate inoperative 5 Kc/s.

ALTERNATIVE MODELS. Type "400X" for medium frequency coverage only, 130 Kc/s. to 2,200 Kc/s. in four wavebands with calibrated scale. Crystal Filter selectivity 250 c/s. and 2 Kc/s. with crystal switched out Type "358/1" for battery operation with headphones. Coverage 31,000Kc/s. to 90 Kc/s. General specification as standard type "358X" but with H.T. consumption reduced to 33 milliamperes at 180 volts.

SUPPLIED TO PRIORITY ORDERS ONLY.





WIDE FREQUENCY RANGE

WEBB'S RADIO

The receiver may be inspected at

14, SOHO STREET, LONDON, W.1

Between 10 a.m. and 4 p.m. (Sats. 10 a.m. to 12 noon.)

Telephone: GERrard 2089.

AERO-NAUTICAL | FIXED | AERO-RADIO BEACONS | RADIO SOUND-ING | GOVERN-MENT | MARITIME MOBILE | COASTAL MOBILE | MARITIME RADIO BEACONS | Interna-tional Broadcast | BROAD-CAST | MARITIME DIRECTION FINDING | AMATEUR | MOBILE

10

W.1

12 noon

MOBIL